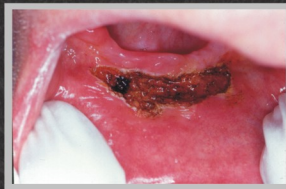
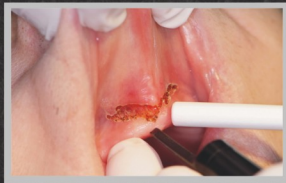


Atlas of

CURRENT ORAL LASER SURGERY



S. Namour
with the support of JP Rocca

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ATLAS OF CURRENT ORAL LASER SURGERY

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Universal-Publishers
Boca Raton

Atlas of Current Oral Laser Surgery

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Universal-Publishers

Boca Raton, Florida

USA • 2011

ISBN-10: 1-61233-028-2

ISBN-13: 978-1-61233-028-0

www.universal-publishers.com

Library of Congress Cataloging-in-Publication Data

Namour, S. (Samir), 1957-

Atlas of current oral laser surgery / S. Namour.

p. ; cm.

Includes bibliographical references.

ISBN-13: 978-1-61233-028-0 (pbk. : alk. paper)

ISBN-10: 1-61233-028-2 (pbk. : alk. paper)

I. Title.

[DNLM: 1. Oral Surgical Procedures--Atlases. 2. Laser Therapy--methods--Atlases. 3. Lasers, Gas--therapeutic use--Atlases. 4. Mouth--surgery--Atlases. 5. Mouth Diseases--surgery--Atlases. WU 600.7]

LC-classification not assigned

617.5'220598--dc23

2011028555

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1	INTRODUCTION	9
2	CO₂ LASER PHYSICS	11
3	CLINICAL PROTOCOL	25
	3.1 Anamnesis and Precautions before Surgery	25
	3.2 Precautions during Surgery	25
	3.3 Precautions in Post-Operative Period	26
4	SURGERY OF BENIGN TUMORS	27
	4.1 Fibromas	27
	4.2 Papillomas	35
	4.3 Botryomycosis	41
	4.4 Warts	45
	4.5 Condylomas	50
	4.6 Epulis	55
	4.7 Mucocele.....	60
	4.8 Pyogenic Granulomas, Peripheral giant cell granulomas (PGCG), Choristomas and lipomas.....	66
5	HYPERKERATOSIS (PRE-CANCEROUS LESIONS)	67
	5.1 Leukoplakia.....	67
	5.2 Lichen planus.....	74
6	VASCULAR LESIONS (ANGIOMAS).....	81
	6.1 Capillary Hemangiomas (Blood Pearl).....	81
	6.2 Hemangiomas	86
	6.3 Lymphangiomas.....	91
7	PROSTHETIC SURGERY	99
	7.1 Denture-induced gingival or mucosal hyperplasia (prosthetic fibroma) 99	
	7.2 Vestibular deepening (increase of the crest length)	106
	7.3 Frenectomy.....	111
	7.4 Floppy ridges.....	114
	7.5 Crown lengthening.....	117

8	ORTHODONTIC SURGERY	121
	8.1 Frenectomy: lingual and labial (big frenulum, diastema).....	121
	8.2 Impacted tooth exposure and bracket placement	129
	8.3 Gingival hyperplasia.....	133
	8.4 Crown lengthening.....	135
9	PERIODONTAL SURGERY	139
	9.1 Gingivectomy	139
	9.2 Gingivoplasty.....	146
	9.3 Frenectomy for periodontal purpose.....	149
	9.4 Vestibular deepening (increase of the attached mucosa).....	154
	9.5 Treatment of acute infection of pericoronal tissues	163
	9.6 Distal wedge.....	168
10	IMPLANTOLOGY.....	173
	10.1 Peri-implantitis treatment.....	174
	10.2 Gingivectomy & Gingivoplasty	177
11	ORAL AESTHETIC SURGERY	181
	Gingival tattoo	181
	Gingival pigmentation (Melanin) removal	185
	Esthetic corrections of the flabby lips	188
12	ROUND TABLE DISCUSSION WITH INTERNATIONAL EXPERTS.....	191

INTRODUCTION

“Imagination is more important than knowledge.”

—Albert Einstein

When Einstein, at the beginning of the 19th century, envisioned the possibility of producing a spontaneous emission of excited atoms, he could not have imagined that electromagnetic wave amplification (MASER) (Townes et al., 1950) immediately followed by Light Amplification by Stimulated Emission of Radiation (LASER) (Maiman et al., 1960) would one day be utilized in such diverse ways.

Today, increasingly versatile and sophisticated lasers are available. These lasers vary in application based on the choice of different technologies, materials (gas, solids, semi-conductors, colorants, etc.), and a diversity of wavelengths. These various wavelengths have made it possible for laser technology to become a safe, simplified, and effective component in current oral surgery.

In the face of these technologies, the problem that might arise for the dental practitioner is choosing the appropriate adapted wavelength for his professional exercise. One of the aims of the present book is to assist practitioners by presenting knowledge regarding wavelengths, technique, and precautions when performing oral laser surgery.

The CO₂ laser beam's efficiency in oral surgery is due to its high absorption level in water. Subsequently, the laser beam provides a bloodless operative field and clear incisions and, if used in the correct mode, is absolutely safe. Due to technical progress in the field, indications are continually enlarging: some of the latest progressions are the super-pulsed and ultra-pulsed modes that represent a new technical approach in oral surgery, with very little carbonization residue.

The present book will examine and discuss some procedures common in different fields of current oral surgery. First, we present an introduction to laser physics, as well as guidelines for proper clinical protocol. Then, we examine how the laser beam can be useful to practitioners in different specialties, such as periodontics, endodontics, orthodontics, implantology, pre-prosthetic surgery, and oral soft tissues diseases treatments. Finally, we engage in a round table discussion with some of the best international experts in the field of oral surgery.

A Short Introduction to the Laser

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Abstract

This chapter aims to describe the fundamental principles of the production of laser radiation. The focus is to convey a general understanding of the underlying physical phenomena without entering into a detailed mathematical formulation. Some practical aspects especially devoted to the use of lasers in the dentistry environment are also covered.

1 LASER Principle

1.1 The Energy of Electrons, Atoms and Molecules is Quantized

Classical Newtonian mechanics applied to a satellite orbiting around the earth does not yield any constraint on the energy of the satellite. Any value of the energy is feasible, but will result in a different orbit. This is no longer true in the nanoworld of electrons, atoms, and molecules where not all energy values (i.e., not all electronic orbitals) are allowed, but instead only *a very few*. The energy of the electrons is “quantized” according to four “quantum numbers” which can have only integer values. This is the reason why a new type of physics called Quantum Mechanics had to be developed in order to explain the energetic behavior of nanoparticles.

In the following chapter, we shall thus represent the discrete energy levels of an atom by drawing a series of horizontal bars, the lowest one being the “ground state” energy level corresponding to the lowest values of all quantum numbers (Figure 1).

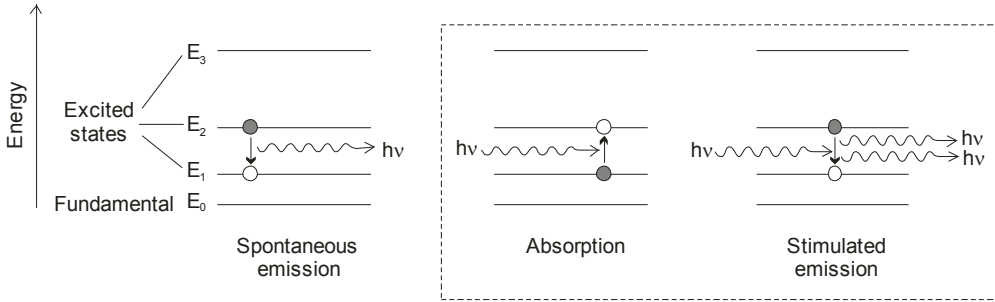


Figure 1. Schematic representation of the energy levels of an atom, with the three processes involved in the interaction with an electromagnetic wave of frequency $\nu = (E_2 - E_1)/h$

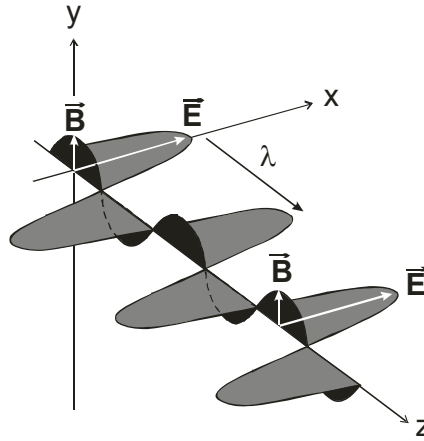


Figure 2. Schematic representation of an electromagnetic wave propagating in the direction of the z-axis. The oscillating vectors $\vec{E}$ and $\vec{B}$ represent the electric and magnetic fields respectively. They are always perpendicular to one another. Most of the effects of the electromagnetic wave are caused by the electric vector $\vec{E}$.

1.2 Electromagnetic Radiation

In order to jump from one orbital to another one, an electron will have to gain or lose energy. Because the electron is a charged particle, it can interact with an electromagnetic radiation and thus can gain or lose energy by absorbing or emitting an electromagnetic wave. Such an electromagnetic wave is represented in Figure 2. It is characterized by a wavelength λ and a frequency ν (Hertz), which is the number of cycles performed during one second. In a vacuum, an electromagnetic wave is traveling at the speed of light $c = 299,792,458$ m/s. The following formula holds for any electromagnetic wave:

$$\lambda \nu = c, \quad (1)$$

Note that the frequency is an invariant of the electromagnetic wave. It determines the “color” of the wave. If the wave passes from the vacuum in another medium, like air, water, or solid, its speed will decrease and only its wavelength will be affected: its direction will be modified (refraction phenomenon), but its color (frequency) will not change. Depending on their wavelengths, electromagnetic radiations are classified into several ranges (Table 1), the most important one for our purpose being the “visible light” range between the infrared and the ultraviolet ranges.

	Wavelength range
γ -ray	$< 0.03 \text{ nm}$
X-ray	$0.03 \text{ nm} \rightarrow 3 \text{ nm}$
Ultraviolet light	$3 \text{ nm} \rightarrow 0.4 \text{ }\mu\text{m}$
Visible light	$0.4 \text{ }\mu\text{m} \rightarrow 0.8 \text{ }\mu\text{m}$
Infrared light	$1 \text{ }\mu\text{m} \rightarrow 3 \text{ mm}$
Microwaves	$3 \text{ mm} \rightarrow 30 \text{ cm}$
Radio	$> 30 \text{ cm}$

Table 1. Wavelength ranges of the electromagnetic spectrum.

As for electrons, atoms, and molecules, the energy of an electromagnetic wave is also quantized. As a consequence, an electromagnetic wave can only exchange energy with a molecule, as an integer number of an indivisible amount “ $h\nu$ ” that depends on its frequency and on the Planck constant $h = 6.62 \times 10^{-34} \text{ Js}$. The energy quantum of the electromagnetic wave is called a “photon.” An electromagnetic wave can thus be represented as a flow of massless particles or “photons,” each of which carries the same quantum of energy.

1.3 Interaction of Electromagnetic Radiation with an Atom

Let us assume that the atom or the molecule is in an excited state. This means that some electrons can jump from their orbital into another one of lower energy closer to the nucleus. Consider an electron in an orbital of energy E_2 (Figure 1) jumping into the energy level E_1 . The amount of energy lost $E_2 - E_1$ will be radiated as one “energy quantum” of an electromagnetic wave according to the Bohr formula:

$$E_2 - E_1 = h\nu , \quad (2)$$

ν being the frequency of the *emitted* wave. Such a process will always happen after a certain period of time, because there is a general law of physics stating that a system always tends to its lowest possible energy level (ground state). The de-excitation

phenomenon is at the origin of any light that can be seen, and it is called *spontaneous emission* (see Figure 1). The reverse process, i.e., a transition from E_1 to E_2 , is possible if and only if the atom of energy E_1 is in contact with an electromagnetic wave of the suitable frequency $\nu = (E_2 - E_1)/h$ and shall result in an energy quantum $h\nu$ being *absorbed* by the atom: this process is called *absorption* (see Figure 1).

From theoretical considerations, Einstein deduced the existence of a third process called “*stimulated emission*” when a photon of energy $h\nu = E_2 - E_1$ strikes an excited atom of energy E_2 . In that case, the excited atom shall immediately jump from E_2 to E_1 and emit a second photon of energy $h\nu$ that has exactly the same characteristics as the initial impinging photon. The two photons will perfectly match and travel in the same direction without any de-phasing, giving rise to a beam of “coherent” light. This process results in amplification of light, i.e., amplification of the electromagnetic wave upon interaction with the molecule.

This process of *stimulated emission* is very efficient because Einstein could predict that it will happen with exactly the same probability as the *absorption* process. However, in order to obtain real efficiency, one has to take account of the number of participating atoms. It is well known that at thermodynamic equilibrium, the number of excited atoms drops very rapidly with the increasing energy i.e., the number of E_1 atoms shall always be much higher than the number of E_2 atoms. Therefore, for more than thirty years, the “stimulated emission” process was considered a scientific curiosity without any practical applications.

1.4 The Inversion of Population

It took until 1951 for Townes to realize that one could get light amplification if the system could be artificially maintained in a state of thermodynamic non-equilibrium where the population of the higher energy level E_2 is always higher than the population of the lower level E_1 . Such a configuration is called “inversion of population.”

Another prerequisite is that the “lifetime” of the higher level, where all the atoms are accumulated, has to be as long as possible. This is a means to avoid, as much as possible, the process of spontaneous emission (i.e., emission that is not triggered by an incoming photon) that happens in any direction and without coherence with the impinging beam of photons. The lifetime of an energy level can be easily determined by spectroscopy. In a usual spectroscopy experiment, an atomic energy level is measured as a “peak” having a certain energy width. This width is inversely proportional to the (spontaneous) lifetime of the level, i.e., the long-lived levels, which will resist spontaneous emission and wait for de-excitation via stimulated emission, appearing as very narrow peaks. These properties provide a clue for selecting suitable materials for possible laser application.

1.5 The First LASER

The LASER acronym stands for Light Amplification by Stimulated Emission of Radiation. It was coined in 1957 by G. Gould, a Ph.D. student of Columbia University. At the same university, Townes had already succeeded in getting amplification in the microwave range (maser), but not in the visible energy range. Theodore Maiman made the first laser operate on 16 May 1960 at the Hughes Research Laboratory in California 1. The laser setup is depicted in Figure 3. A coiled flash lamp was used to excite a ruby rod and provide the population inversion. The electronic levels of ruby are schematized in Figure 4.

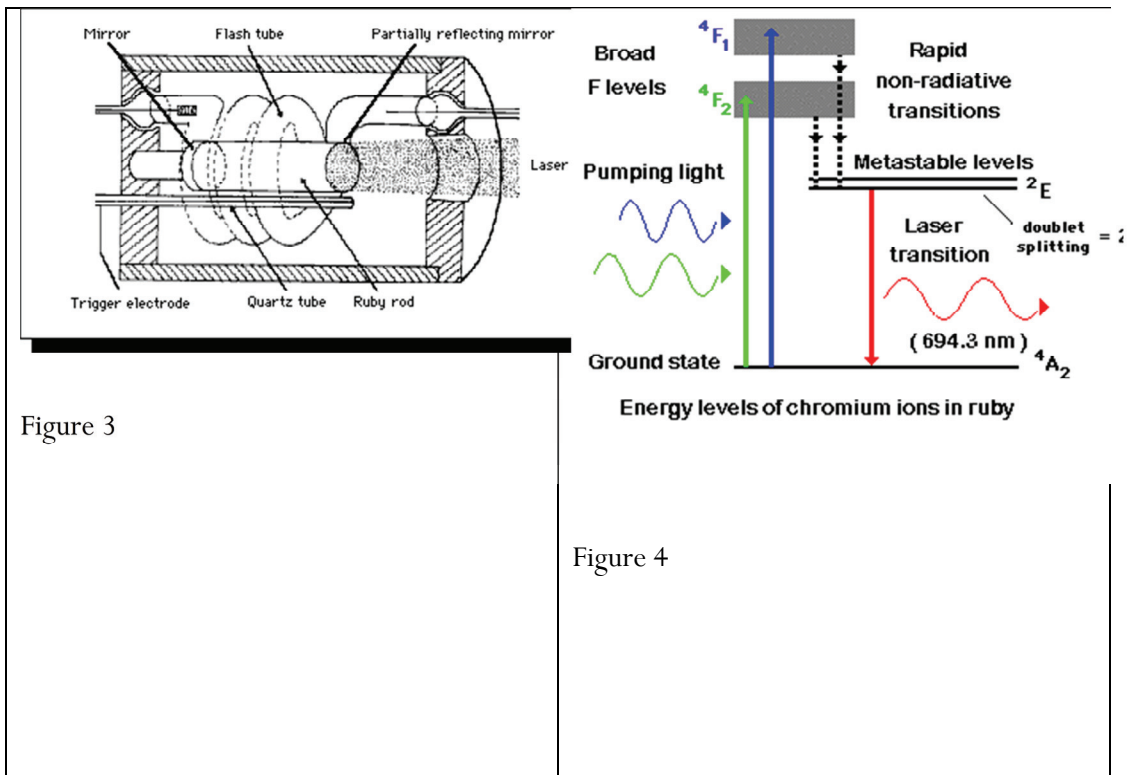


Figure 3

Figure 4

Nature, August 6, 1960, Vol. 187, No. 4736, pp. 493-494.

2 Laser Beam Characteristics

The main difference between lasers and incoherent light sources is the laser's ability to concentrate all the optical power into a low diverging monochromatic beam and short optical pulses with high peak power. This is achieved by placing the optically active medium into a laser cavity constituted by two autocollimated mirrors, such that only the beam that propagates along the cavity axis can be amplified by multi-passes through the active medium. Several techniques are available to constrain the

release of the optical energy stored in the “population inversion of the gain medium” into a laser beam with the appropriated spatial, spectral, and temporal characteristics.²

The use of long cavities with intra-cavity diagrams, small diameter gain medium, and cavity mirrors with a higher reflection coefficient in the centre favor the generation of the “TEM 00 beam” or “Gaussian beam,” whose diameter and divergence reach the minimum values limited by the diffraction of light. As represented in Figure 5, the radial distribution of this ideal beam profile follows a Gaussian shape, the diameter of which increases with the propagation distance according the divergence angle, θ_d

$$\omega_0 = 2\lambda/\pi \theta_d \quad (3)$$

where, ω_0 , is the diameter of the beam at its waist.

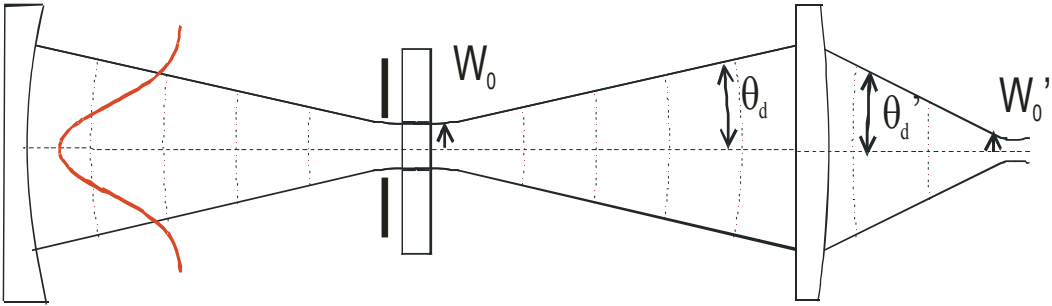


Fig. 5 The left part shows a laser cavity with an intra-cavity diaphragm for the generation of a Gaussian beam. The right part shows the propagation of the Gaussian beam through the optics. The Gaussian represents the beam intensity distribution. The dotted line represents the slightly curved wave front, e.g., the region where the electric field represented in Fig. 2 reaches its maximum. The continuous lines give the limits containing 86% of the beam power.

Equation (3) also sets the limit of the minimum achievable laser spot diameter. For example, a beam diameter of 1 cm focused by a lens with 100 mm focal length leads to a minimum spot diameter of 10 μm at the wavelength of 1 μm . If aberration is negligible, the quantity $\frac{\pi\omega_0}{2\lambda}\theta_d = M^2$ is conserved as the beam propagates through different optics. Therefore, M^2 is the measure of the beam spatial profile quality and approaches the minimum value of 1 for the highest beam quality near the theoretical diffraction limit.

The energy distribution of the states E_1 and E_2 , defining the laser transition, will set the spectral bandwidth of the laser, $\Delta\nu$. Although this is a key parameter for spectroscopic applications of lasers, laser bandwidths are usually negligible in front of the broad absorption bands of biological molecules, and the laser beam can be considered as monochromatic in medical applications. Finally, the concentration of optical ener-

gy in short laser pulses has important implications for the effect of the laser beam on biological tissues. Pulse durations of the order of a few seconds or a few μs are obtained by modulation of the continuous operation of the laser using mechanical shutters or modulation of the electric power. Pulses with duration of a few nanoseconds are achieved by using the Q-switching method. This technique implies using an intra-cavity fast shutter, usually made by combining a polarizer with a Pockels cell, which prevents laser oscillation before high optical energy is stored in the population inversion. When the shutter opens, its optical energy is released in a short pulse, the duration of which corresponds to a few round-trips of the light in the cavity. Even shorter pulses with duration down to the picoseconds and femtoseconds range can be generated by mode-locking the laser, e.g., concentrating the optical energy into a few millimeters- or micrometers-long pulse that will oscillate in the cavity. This is achieved by inserting in the cavity either a high-frequency shutter based on acoustic waves, or any non-linear optical device, such as a non-linear absorbing dye or a non-linear mirror that favors the oscillation of a short pulse with high peak power. Pulse duration as short as a few femtoseconds is achieved with Ti: a sapphire laser. As we will discuss hereafter, the majority of medical applications require a deposition of energy density ranging from 1 to 10^3 Joule of optical energy per cm^2 of irradiated tissue. Depending on the pulse duration, τ , which can vary from several seconds for a continuous laser to a few hundred femtoseconds for a mode-locked laser, the peak intensity can vary by 12 orders of magnitude from $\sim 10^{12}$ to ~ 1 Watt per cm^2 . This latter parameter, along with the laser frequency, governs the nature of the tissue-laser interaction.

3 Laser Technologies

One important class of medical lasers³ uses an electric discharge in gas as the active medium. Such discharge results from a cold plasma where electrons are accelerated by the electric field and further ionize adjacent molecules. During the relaxation from their highly excited state to their fundamental state, the molecules will be trapped in meta-stable excited states, E_2 , evoking population inversion with the lower empty level E_1 . In the very common CO_2 laser, the laser transition takes place between vibrationally excited states, hence the particularly long emission wavelength of $10\text{ }\mu\text{m}$. In other gas lasers, the emission occurs between electronic excited states of atoms or ions with emission wavelengths lying in the visible light and near UV range (He-Ne laser $\sim 633\text{ nm}$, argon ion laser ~ 488 or 514 nm , krypton $\sim 647, 568.2, 520.8$ or 476.2 nm , Cadmium: 425 or 325 nm). These lasers provide a continuous beam, or can be pulsed down to microsecond pulse durations by modulation of the discharge high voltage, but cannot reach high peak power because of the limited size. Excimer lasers form a particular class of gas laser where the level, E_2 , is the molecular complex of electronically excited atoms formed in powerful transient gas discharge, while the lowest level, E_1 , is the dissociated form of this complex. Such lasers present the ad-

vantage of emitting nanosecond long pulses in the UV (Ar-F: 193 nm, Kr-F: 248 nm, Xe-F: 351 nm). The “Solid-state”² qualification refers to lasers where the active medium is made of ions trapped in transparent glasses. The ions are excited by flash lamp irradiation. This technology enables the implementation of the Q-switching and mode locking techniques for the emission of short and energetic nanosecond and picosecond pulses (Nd-YAG: 1 μm , ~ 20 ps, ~ 100 ps, ~ 10 ns, ~ 100 μs , Nd-YLF: 1 μm , ~ 20 ps, ~ 100 ps, ~ 10 ns, 100 μs , Ti: sapphire: 700- 900 nm, ~ 100 fs). Among these lasers, the Ho:YAG and, particularly, Er:YAG present emission lines down to the infrared spectral ranges (Ho:YAG: 2.1 μm , 10 ns, ~ 100 μs , Er:YAG: 2,78 μm , 10 ns, ~ 100 μs). Semiconductor lasers, based on diode junctions, present the advantage of cost effectiveness, and high-energy conversion yield from electric to optical power. Their emission wavelength can be adjusted by the semiconductor constitution from the blue (InGaN: 416 nm) down to the infrared (AlGaAs/GaAs: 1200-1600 nm, lead salts diode: down to 30 μm). They usually generate continuous beams, but they can be pulsed down to nanosecond duration with limited energy because of the limited volume of the active medium.⁴ Dye lasers⁵ have been developed to allow the user to adjust the beam output frequency anywhere within the visible spectral range from 450 to 900 nm within minutes by changing the appropriate dye solution. The particular dye is dissolved in a liquid solvent and is pumped by another visible laser. Depending on the pulse duration of the pump laser, they can generate picoseconds, nanoseconds pulses, or continuous waves. Their main disadvantage is their complicated maintenance, since the dye solution must be periodically adapted. Continuous tunability of the laser frequency can now be obtained using non-linear optical devices such as optical parametric oscillators (OPOs) or generators.⁶ These devices are built around non-linear crystals that will act as frequency converters when irradiated at high intensity of the order of 10^8 to 10^{10} W/cm² according to the sum frequency formula of the second order non-linear optical process: $\nu_0 = \nu_1 + \nu_2$. The KTP laser (532 nm) is an example of such a device, where the frequency of the Nd: YAG laser (1.064 μm) beam is doubled ($\nu_0 = 2 \nu_1$) in a crystal of KTiOPO_4 . The available non-linear crystals enable us to cover the complete spectral range from ~ 250 nm to 20 μm . OPOs will generate pulses with duration reflecting that of the pump laser, e.g., typically in the nanoseconds, picoseconds, and femtoseconds ranges.

4 Laser-tissue Interaction

The medical applications of lasers rely on the possibility to induce local necrosis, local etching, or fragmentation of tissues⁷. The particular effect depends on the laser beam and tissue characteristics and can be evaluated using the following models of the processes of laser beam absorption and propagation in the tissue, diffusion of heat, and the initiation of local plasmas.

4.1 Laser Light Absorption

Light absorption follows a simple scaling law: the rate of energy absorption per molecule is equal to the local beam intensity I multiplied by a cross-section, s . If N is the molecular concentration, the absorbed intensity per unit volume and time, S , reads

$$S = \alpha I, \quad (4)$$

where $\alpha = s N$ is the absorption coefficient of the tissue. α becomes significant only when the frequency of the laser beam, ν , matches that of a molecular transition according to equation (2). If ν lies in the infrared spectral range, the laser beam couples predominantly with molecular vibrations. Since the ubiquitous H_2O molecules show an OH vibration at $2.7 \mu\text{m}$, α in soft tissues reaches the highest value $> 10^4 \text{ cm}^{-1}$ near the particular wavelength of the Er:YAG laser ($2.94 \mu\text{m}$) but can be as low as $\sim 10^0 \text{ cm}^{-1}$ at the wavelength of the Nd:YAG laser ($1.06 \mu\text{m}$). Because of the small photon energy $h\nu$ in the infrared, such an excitation cannot evoke any change in the molecular conformation nor break chemical bounds, but is rapidly statistically distributed among the other vibrations and rotations of adjacent molecules, i.e., it decays into heat. For ν in the visible, the absorption occurs by excitation of the molecular electronic system. Although such a process may lead to photochemical effects, e.g., changes of the chemical properties of the excited molecules, as exploited in photodynamic therapy or observed naturally in some important biological reactions such as photosynthesis, this excitation often decays into heat. Finally, the higher frequency UV light is classified as ionizing radiation because it induces more severe electronic excitations, which can lead to ionization and chemical bond breaking.

The linear absorption law (equation(4)) and its resonant character holds as long as the electric field associated with the laser beam remains smaller than the one maintaining the electrons in their molecular orbitals. Indeed, above the so-called “optical break-down” threshold that occurs at beam intensities in the order of 10^{10} W/cm^2 , molecules are ionized and dissociate independently of the laser beam frequency.

4.2 Light Propagation

The integration of equation (4) leads to the expression describing the laser intensity attenuation as it penetrates into a tissue:

$$I(z) = I(0) e^{-\alpha z}, \quad (5)$$

where $I(z)$ is the beam intensity at the depth z . From equation (5), we deduce the penetration depth of the light into the tissue:

$$L = I / \alpha \quad (6)$$

Equations (5) and (6) are not valid if strong scattering of the light occurs onto the inhomogeneities of the tissue. Such scattering is parameterized by the scattering coefficient (α_s) and scattering anisotropy (g). α_s adds up to α to give the total attenuation coefficient of the coherent beam in the tissue, while the geometrical factor g varies from -1 to 1 if the scattering is predominantly backward, isotropic and forward, respectively. The light propagation in such a turbid medium cannot be described by a simple analytical solution. Fortunately, different calculation methods⁷ enable us to predict that the diffuse light local intensity can be evaluated using equations (5) and (6) with an effective diffusion length, L_{eff} , and diffusion coefficient α_{eff} evaluated to

$$L_{eff} = 1 / \alpha_{eff} = 1 / \sqrt{3 \alpha (\alpha + \alpha_s (1 - g))} \quad (7)$$

when $\alpha_s \gg \alpha$ [8]. Data from ref. 7 and 8 show that beam attenuation is usually dominated by scattering with L_{eff} of soft tissues lying between 10 and 500 μm in the visible spectral range.

4.3 Heat Diffusion

When the absorbed optical energy decays into heat, the local temperature evolution of the tissue can be predicted by solving the heat diffusion equation:

$$\frac{\partial T(\vec{r})}{\partial t} = k \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \right) T(\vec{r}) + \frac{1}{C} S(\vec{r}), \quad (8)$$

where T and S , defined by equation (4), are the local temperature increase and heat source, respectively. C is the heat capacity per unit of volume that takes typical values between 1.5 and 4.5 J / K cm³. k is the temperature conductivity, which is close to $1.4 \cdot 10^{-3}$ cm²/s for most tissues⁹. This value indicates that the temperature increase will “diffuse” on distances of the order of 1 μm and 100 μm after a time delay of 1 μs and 10 ms, respectively ($1 \mu\text{m} \sim \sqrt{1 \mu\text{s} k}$, $100 \mu\text{m} \sim \sqrt{10 \text{ms} k}$). If we compare this temperature penetration depth to the shortest light penetration depth in tissue as observed for Er:YAG laser ($L \sim 1/10^4 \text{ cm}^{-1} \sim 1 \mu\text{m}$), we conclude that the heat will not escape the irradiate area if the laser pulse duration is smaller than 1 μs . The most important thermal effects are local necrosis of the tissue by coagulation that occurs between 60°C and 70°C and local etching by vaporization at 100°C. Continuous wave or pulsed CO₂ lasers are often selected for this operation because of the strong absorption of these moist tissues at 10 μm .⁷

4.4 Plasma Formation

Achieving optical breakdown in a collection of atoms and molecules will result in the formation of a plasma of free electrons, ions, and excited molecules. The local sublimation and decomposition of the tissue in the plasma evoke a transient pressure increase in the neighboring tissue. This takes the form of shock waves, which, in the case of soft tissues, can be accompanied by cavitation, e.g., the formation of gas bubbles with diameters that oscillate to accommodate the mechanical energy, and by jet formation, e.g., ejection of tissue due to the collapse of the cavitation bubbles near the surface. The damage due to these mechanical side effects is referred to as photo-disruption. The local plasma-induced ablation can be favoured over the non-local photodisruption effects by minimizing the energy injected in plasma. A phenomenological modeling of the plasma formation¹⁰⁻¹³ leads to the following evaluation of fluency threshold (F_{th}) required to initiate the plasma:

$$\eta F_{th} = \frac{s}{2} + \sqrt{\left(\frac{s}{2}\right)^2 + \frac{\tau}{2\tau_c}} + \frac{\tau}{\tau_d}, \quad (9)$$

with the phenomenological parameters τ_c , and τ_d being the mean collision and mean diffusion time of electrons. s , reflects, on a logarithmic scale, the necessary increase of electron density from the initial breakdown to sustained plasma. Adjusting τ_c , τ_d and s to 1 fs, 500 ps, and 18 respectively, enables us to mimic the experimental observations that, for all tissues, F_{th} evolved as $\sim \sqrt{\tau}$ for pulse duration ranging from a few ps to few μ s, as $\sim \tau$, for longer pulse durations, and is independent of τ , for sub-picoseconds pulses. Using picoseconds or femtoseconds pulses enables us to keep F_{th} as small as possible and to suppress the disruptive effect that appears omnipresent using nanosecond or longer pulses. η is the ionization probability and appears higher for teeth and corneas (~ 13 [J/cm²]⁻¹) than for soft tissue (~ 5 [J/cm²]⁻¹). These numbers indicate that plasma induced ablation on teeth is already initiated at fluencies of 10 J/cm² for 10 ps long pulses. Although lithotripsy of urinary calculi is an example where photo-disruptive effects can be exploited in a particular therapy, early trials using ruby and CO₂ lasers to replace the mechanical drills with laser etching in caries therapy have long been discouraged. However, suppression of the thermal and photo-disruptive effects has been demonstrated more recently using 30 ps laser pulses generated by a Nd:YLF laser¹⁴.

4.5 Photoablation by UV Beam

Ablation of polymer and biological tissue without thermal damage can be achieved at lower fluency by using the nanosecond pulses of an Excimer laser,¹⁵⁻¹⁶ in particular, the ArF laser emitting at shortest wavelength of 193 nm. The efficiency of the

process relies on the fact that the absorption of a single UV photon can ionize or bring the molecule into a pre-dissociated state even at low fluency where the light absorption still obeys equation (4). Indeed, the photon energy at 193 nm (6,4 eV) is higher than the dissociation energy of most chemical bonds (O-H: 4.8 eV, C-C: 6.4 eV). The ablation depth z_{abl} as a function of fluency can be derived from equations (4) and (5), assuming that the tissue will decompose and be ejected if the concentration of pre-dissociated molecules, e.g., the local intensity (I_{th}) or fluency (F_{th}), reaches a particular threshold value:

$$\alpha I(z_{abl}) = \alpha I_{th} \quad \text{or} \quad z_{abl} = \frac{I}{\alpha} \ln\left(\frac{F}{F_{th}}\right) \quad (10)$$

Typical ablation rate is 0.5 $\mu\text{m}/\text{pulse}$ for fluency of a few 0,1 J/cm^2 for a cornea irradiated by ArF Excimer laser pulses.¹⁵ Higher fluencies initiate plasma that absorbs the incident UV beam, limiting the ablation rate to about 1 $\mu\text{m}/\text{pulse}$. Such a low ablation rate has discouraged the use of this process in dentistry.⁷

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CLINICAL PROTOCOL

3.1 Anamnesis and Precautions Prior to Surgery

Precautions and protocols followed for conventional surgeries should be respected for oral laser surgeries:

1. Consultations and assessments: The practitioner should take into consideration the personal history and complaints of the patient. Clinical examination and complementary examinations (RX, MRI, bleeding level, etc.) should be completed prior to surgery. It is mandatory that a biopsy be carried out before any ablation of oral diseases, tumors, hyperkeratosis, lesions, or unusual mucosa. Anamnesis of the patient and different examinations can reveal if the patient has any risk factors. Make a diagnosis before any surgery.
2. The patient should be informed about the surgery procedure, the eventual risks of the surgery, and the undesirable effects and side effects, if any.

3.2 Precautions during Surgery

Observe similar precautions to those respected for conventional surgeries. It is necessary to protect the eyes of the practitioners, nurses, assistants, and patient with adapted protective glasses. For patients considered risky cases (hemophilic, diabetic, transplanted [organ grafted], immune-deficient, healing deficient, or with heart diseases [endocarditic, shunt, etc.], a weakened immune system, or if the patient is in chemotherapy, etc.), it is highly recommended that the wound be sutured at the end of the laser surgery.

3.3 Precautions in Post-Operative Period

A similar procedure to that used in conventional surgeries is respected for oral laser surgeries. Prescribe an oral disinfecting solution for a maximum of 10 days to avoid the risk of secondary infection of the wound in the post-op period. For patients considered high-risk, it is highly recommended that the wound be sutured at the end of the laser surgery. Prescribe the adapted antibiotics and precautions for the post-op period.

On the other hand, for patients considered healthy, the decision about which antibiotics and analgesics to prescribe depends on the kind and nature of the disease, topography, and the size of the ablated tissues. This decision is left to the practitioner's discretion.

3.4 Clinical Procedure for Oral Laser Surgeries

Below is a short description of the clinical protocol for oral laser surgeries, in order to avoid redundancy in the following chapters.

General protocol for ablation procedures:

- Respect similar precautions and preparations to those adopted for conventional surgeries (precautions and preparations of the practitioner, nurses, assistants, patient, the surgery site, sterile material, etc.)
- Laser settings
- Protect the eyes of the practitioners, nurses, assistants, and patient by wearing adapted protective glasses
- Anesthesia, if required, for the surgical site
- Protect the tissues surrounding the surgical site in order to avoid any contact between the laser beam and the healthy tissues (hard dental tissues, soft oral tissues, etc.)
- Demarcate with a laser beam the limits of the area to be removed before starting the surgery
- The carbonized tissues should be removed from the surgical site (except in some specific surgical cases). A cotton swab soaked with a Lotagen[®] (36% dihydroxydimethyl-diphenylmethane-disulfonic polymerized) solution can be used.
- Recommendations for the patient
- Prescriptions for the post-operative period
- Consultations and recalls during the post-op period

SURGERY OF BENIGN TUMORS

4.1 Fibroma

Even if the term *Fibromatosis* is used to denote the different pathological entities, Fibroma is a neo-formation mainly composed of connective tissue. Both peripheral and central lesions consist of variable proportions of collagen and fibroblast-like cells.

Fibroma is rare, even if the geographical differences in the incidence of lesions are evoked.

Macroscopically, Fibroma usually manifests as a firm, rounded tumor, clearer than the surrounding tissues and well demarcated, covered with ordinary mucosa (no erosion, no hyperkeratosis). The most common clinical presentation is a painless mass that involves cheeks, lips, and tongue.

Local traumas, such as traumatic vicious injury, diaphnosis, or occlusal problems, are the most common causes of Fibroma (“irritation Fibroma”).

As a benign tumor, Fibroma may grow aggressively. Rapid identification and surgery are recommended.

The treatment of choice is a surgical resection.

In the case of irritation Fibroma, etiological factors must be considered and treated before or during surgery.

Definition	
Macroscopic aspects	Firm, clearer than surrounding tissues, healthy mucosa without erosion and/or hyperkeratosis.
Etiology	Traumatic vicious injury, diaphnosis, occlusal problems

Laser irradiation conditions:

Mode	Continuous or super-pulsed
Output power	3 to 6 Watts
Focus/ defocus mode	Focus mode
Surgery	Removal by excision

Clinical case 1:

Caucasian female, 43 years old, had a traumatic vicious injury (sucking and biting of her lower lip). She developed a reactionary Fibroma, well circumscribed. The tumor was described by the patient as an asymptomatic, slow-growing lesion (submucosal growth). Size: around 5 mm. The clinical diagnosis was made after confirmation by biopsy. However, at the end of the surgery, the entire excised tumor was sent for histological examination.



Fig 4.1.1: Clinical view of the lower lip Fibroma. Palpation confirms the fibrous characteristics of the tumor. The lesion is pale compared with the surrounding tissues. There is an absence of erosive or hyperkeratosis aspect.

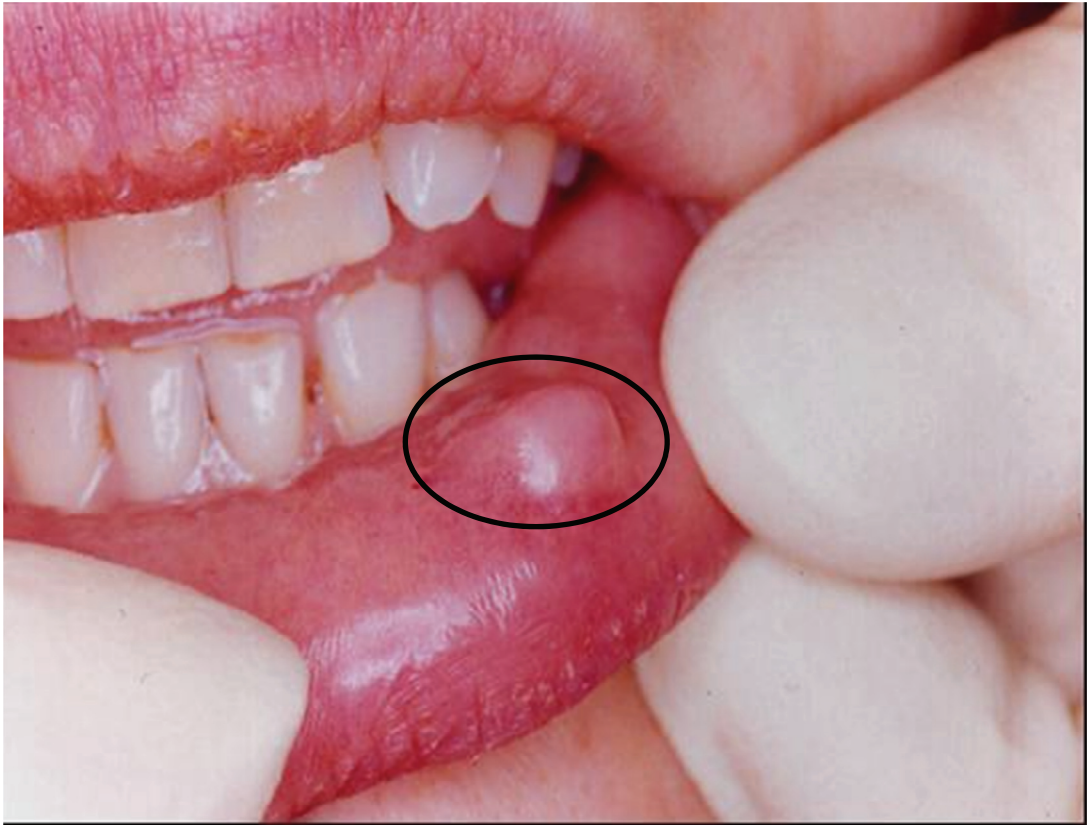


Fig 4.1.2: Clinical view of the lower lip Fibroma. After an injection of anesthesia, the laser beam is used to demarcate the limit of the future tumor excision (schema made with a black circle).



Fig 4.1. 3: View of the wound at the end of the surgery. The tumor was removed by excision at its implantation. Demarcation of the limit of ablated tissues was made by the laser beam around the tumor prior to the excision (1 mm from sound margin epithelial tissues). The hemostatic effect of the CO₂ laser is also noted. Carbonization removed to ensure a rapid and better quality of healing. The excised tumor was sent for histopathological examination.

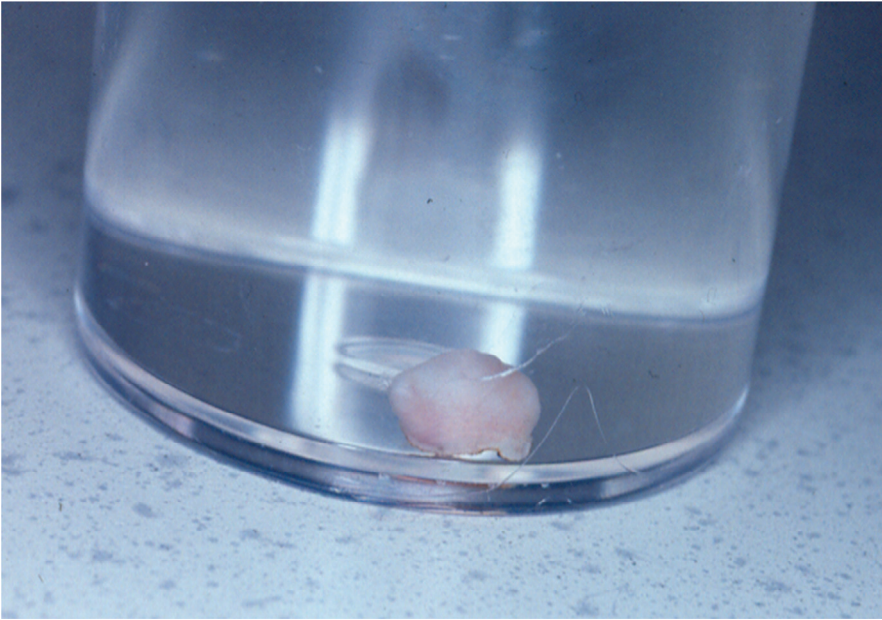


Figure 4.1.4: Biopsy specimen fixed in a solution of formalin 10%.

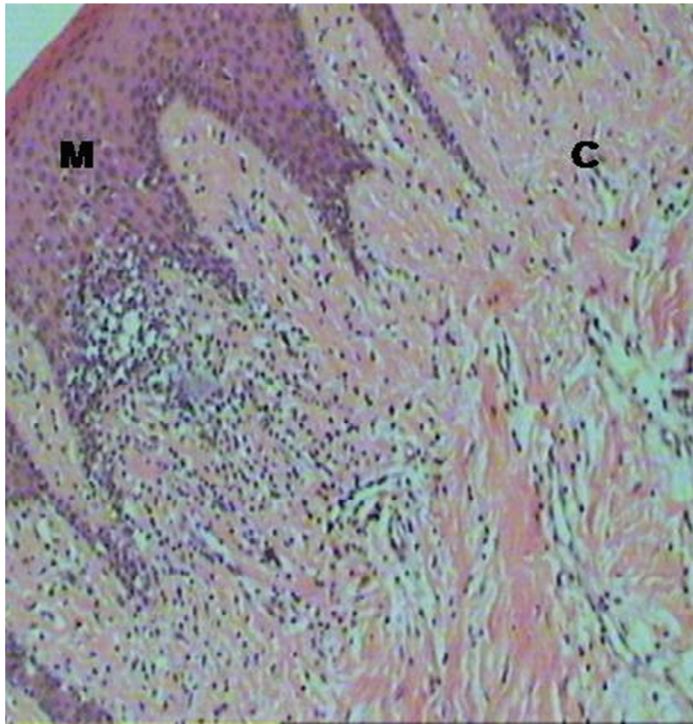


Figure 4.1.5: Histological examination of the sample shows the existence of a reactionary Fibroma. M = mucosa. C = fibrous connective tissue. Close to the mucosa, the connective fibers are perpendicular to the external surface. (Original magnification = 100 X.)

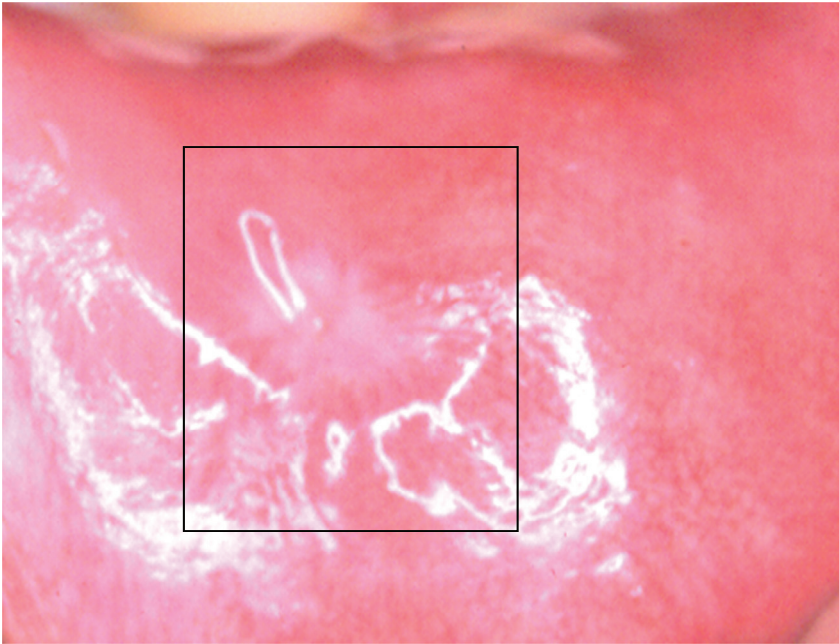


Figure 4.1.6: View of the wound site two weeks after surgery. The healing is not yet complete. The persistence of some fibers covering the wound site (appeared 6 hours after laser surgery) can be seen.



Figure 4.1.7: Healing after 2 weeks of post-op. There is no existence of a scar or a fibrous healing and no distortion in the symmetry of the lip.

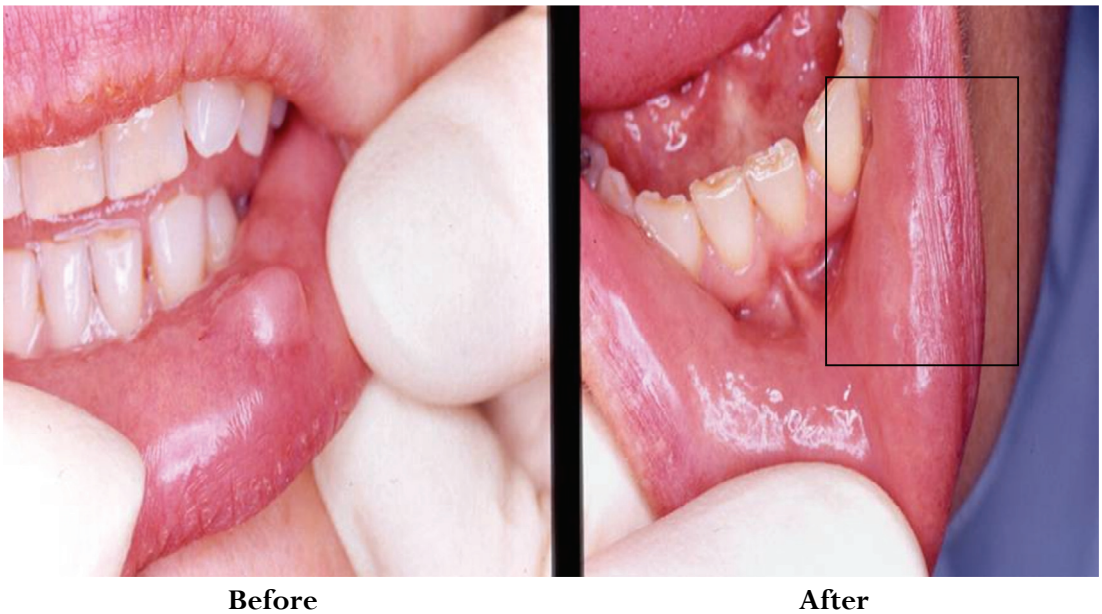


Figure 4.1.8: Views of the lower lip before and after surgery.

Clinical case 2:

Male, Caucasian, 48 years old, healthy, had a traumatic vicious injury (biting his lower lip). He developed a reactionary Fibroma that was well circumscribed. The tumor was described by the patient as an asymptomatic, slow-growing lesion. Size: around 8 mm. The clinical diagnosis was made after the confirmation by biopsy. However, the entire excised tumor was sent for histological examination.



Fig 4.1.9: Clinical view of the lower lip Fibroma. The palpation confirms the fibrous characteristics of the tumor. The lesion is pale compared with the surrounding tissues. Absence of erosive or non-normal aspect.



Fig 4.1.10: View of the wound at the end of the surgery. The tumor was removed by excision at its implantation. Demarcation of the limit of excised tissues was made by the laser beam around the tumor prior to the excision (1 mm from sound margin epithelial tissues). The hemostatic effect of the CO₂ laser is noted. The carbonization was removed. The excised tumor was sent for histo-pathological examination.



Fig 4.1.11: Healing after 2 weeks of post-op. Note the complete recovery of the surgical site. There is no existence of scar or fibrous healing and no distortion in the symmetry of the lip.

The first post-op recall was at approximately two weeks. For this healthy patient, no antibiotics or anti-inflammatory drugs were prescribed during the postoperative period. Only an oral antiseptic mouth rinse solution was prescribed to prevent an eventual secondary infection of the wound (the rinse was to be used three times per day after meals). There was no need for suturing. Carbonization was easily removed using a cotton swab soaked with a Lotagen[®] (36% dihydroxydimethyldiphenylmethane-disulfonic polymerized) solution.

4.2 Papilloma

It has been demonstrated that viral infection (HPV: human papilloma virus) is involved in the etiology of papilloma. Its color is generally white due to the keratin component, and it has a floppy consistency. Clinically, papilloma is usually stalked and may have a cauliflower-like surface appearance. The lesion can also have a broad base and, more rarely, a smooth surface. Papilloma evolves from the epithelial tissue, grows slowly, and mostly remains benign.

In the oral cavity, Papilloma (as well as Condylomas) is frequently located on the palate, tongue, cheeks, and lips.

From an epidemiological point of view, the lesions of this disease are auto-inoculated and may be transmitted as a venereal disease.

Definition	Asymptomatic tumor, keratinized epithelium, exophytic proliferation, HPV viral infection is involved in its etiology
Macroscopic aspects	White lesion, cauliflower-like surface aspect
Etiology	HPV infection, Traumatic injury

Laser irradiation conditions:

Mode	Continuous
Output power	4 Watts
Focus/ defocus mode	Focus mode
Surgery	Removal by excision. Effective protection against exhaust fumes from surgery site.

Clinical case:

Caucasian male, 31 years old. Clinical appearance of papilloma: cauliflower-like surface with a large base close to the maxillary lateral and central incisor (Fig. 4.2.1). Biopsy was conducted before surgery to secure a definitive diagnosis. The tumor was removed by a large excision involving 2 mm of sound and healthy tissues from the deep and surrounding tissues (Fig. 4.2.2). During surgery, practitioner and assistants should take care and consideration that the exhaust fumes from the laser surgery site can contain a virulent HPV virus (efficient masks and a sucking system should be used). The carbonization was removed and the excised tumor was sent for histopathological examination (Fig. 4.2.3). The healing of the operated site was satisfactory after 2 weeks of post-op (Fig. 4.2.4).

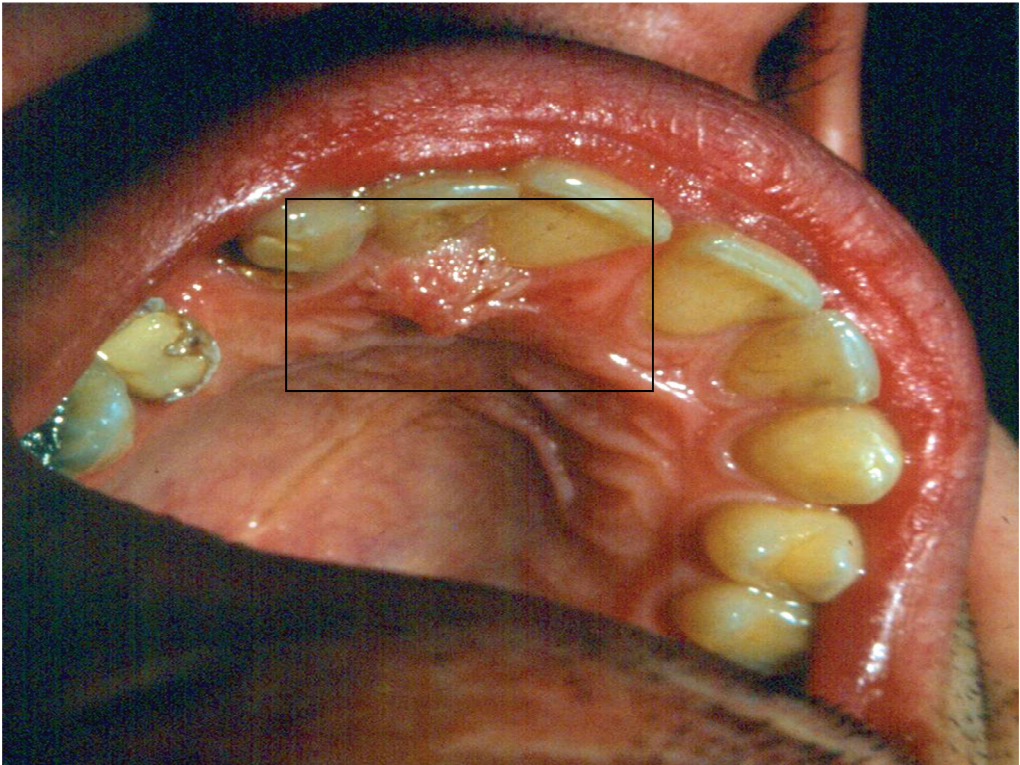


Fig 4.2.1: Pre-operative view of the palate Papilloma



Fig 4.2.2: The excision was performed deeply (2 mm in depth, reaching the palate bone, in this case) and widely (removal of 2 mm from the surrounding tissues) in order to ensure a deep and large ablation of the lesion and avoid recurrence. The surgery field was bloodless.



Fig 4.2.3: Histological examination of the sample proved that the tumor was a papilloma. M: Mucosa tissue; C: connective tissue; Original magnification: 40 X.

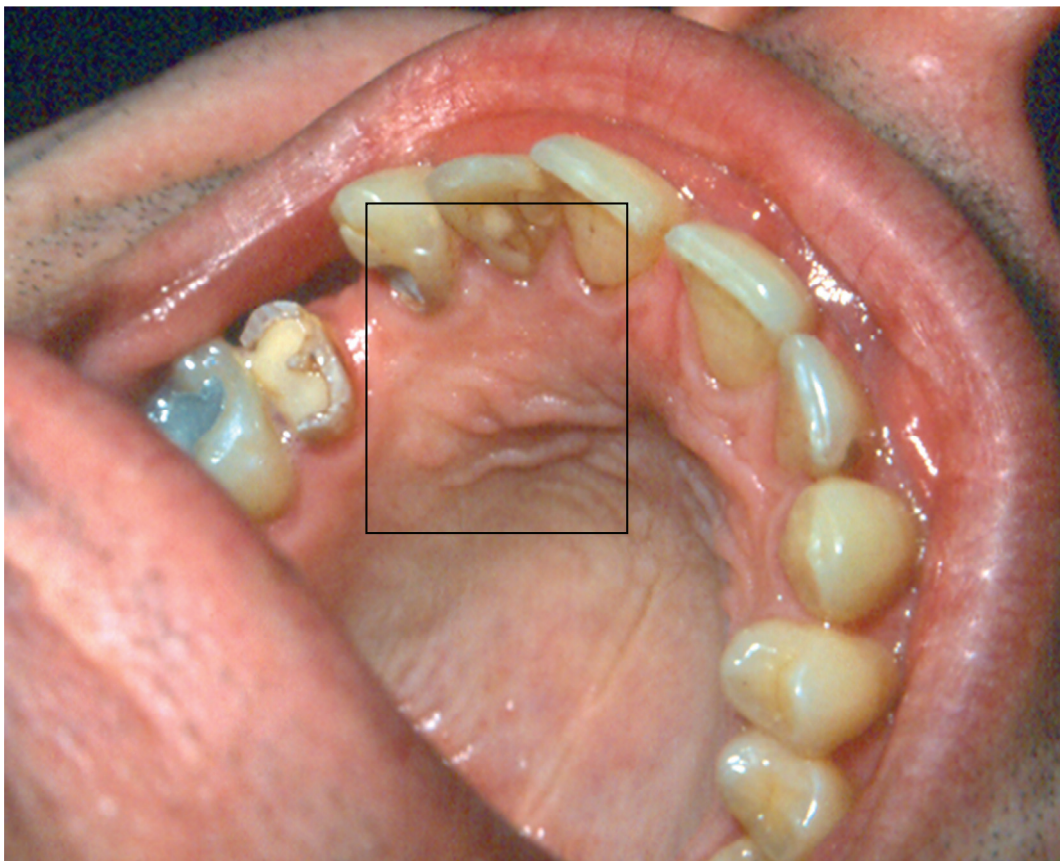


Fig 4.2.4: Healing after 2 weeks of post-op. The complete recovery of the surgical site is evident. There is no existence of scar or fibrous healing.

Healing time is less than two weeks. For this healthy patient (not a risky case), no antibiotics or anti-inflammatory drugs were prescribed during the post-operative period. Only an antiseptic mouth rinse solution was prescribed to prevent an eventual secondary infection of the wound (used three times per day after meals). There was no need for suturing. A CO₂ laser beam is helpful for the treatment of this kind of lesion (viral infection) because of the high decontamination potential of this type of laser (important heat generation at the surgical site). It is recommended that practitioners excise these tumors widely (2 mm from surrounding healthy tissues) and deeply ($\pm$ 2 mm) to avoid a recurrence of the lesion. Carbonization was removed easily using a cotton swab soaked with a Lotagen[®] (36% dihydroxydimethyldiphenylmethane-disulfonic polymerized) solution. The excised tumor was sent for histo-pathological examination.

4.3 Botryomycosis

Botryomycosis is described as a sub-acute or chronic bacterial infection characterized by a granulomatous response and granules. In rare cases, this indolent infection has been described in patients with immune-deficiency and tissues with a decreased healing ability.

This bacterial pseudo-mycosis has been associated with a variety of aerobic and anaerobic bacteria, usually endogenous flora and low virulence micro-organisms. Microscopically, micro-organisms appear to be encapsulated in those granules, which are thought to protect them from the effects of a standard course of antibiotics.

Treatment proposals generally include surgical resection whenever possible, with prolonged appropriate antibiotics.

The CO₂ laser makes surgical excision feasible without any surrounding damage. This type of laser surgery has a sterilization potential, which is helpful for this kind of lesion, and treatment does not need to include any antibiotic therapy. In the following case, it was observed that the oral lesion did not recur after initial laser surgical treatment.

Definition	Asymptomatic; stalked; exophytic proliferation
Macroscopic aspects	Granulomatous and exophytic proliferation
Etiology	Chronic bacterial infection in predisposed patients

Clinical case:

Caucasian female, 41 years old, had a clinical appearance of Botryomycosis (Fig. 4.3.1). A biopsy was conducted before surgery to secure a definitive diagnosis (Fig. 4.3.2). The excision involved a large part of surrounding healthy mucosa (removal of 2 mm from the surrounding healthy tissues and 2 mm in depth) in order to avoid any possibility of infection recurrence. The surgery was bloodless. There was no need for suturing (Fig. 4.3.3). The carbonization was removed. The healing was satisfactory after 2 weeks. There was no recurrence at 6 weeks into the post-op period (Fig. 4.3.4).

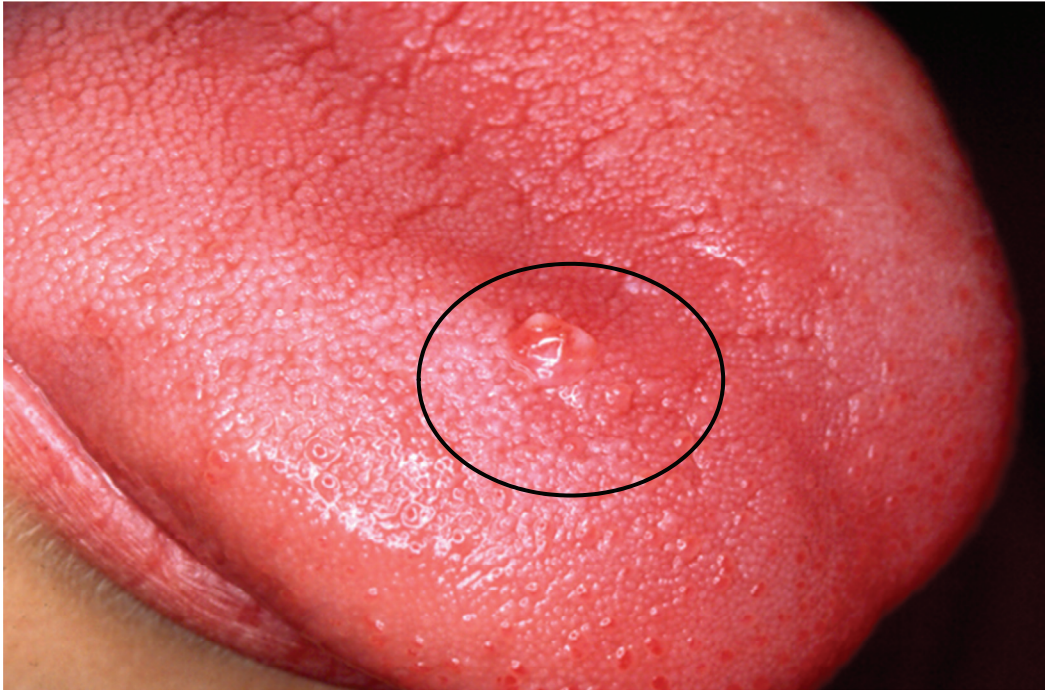


Fig 4.3.1: View of the botryomycosis developed on the tongue of the patient. The black circle schematizes the future limit of ablation.

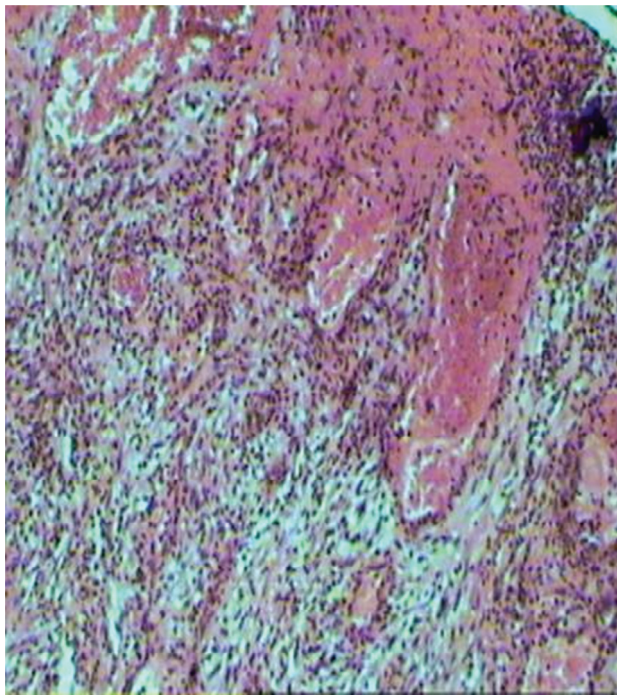


Fig 4.3.2: Microscopic view of the Botryomycosis. The center of the tumor shows an important inflammatory reaction.



Fig 4.3.3: The excision involved a large part of the surrounding healthy mucosa (removal of 2mm from the surrounding healthy tissues and 2 mm in depth) to ensure a complete ablation of the affected area.

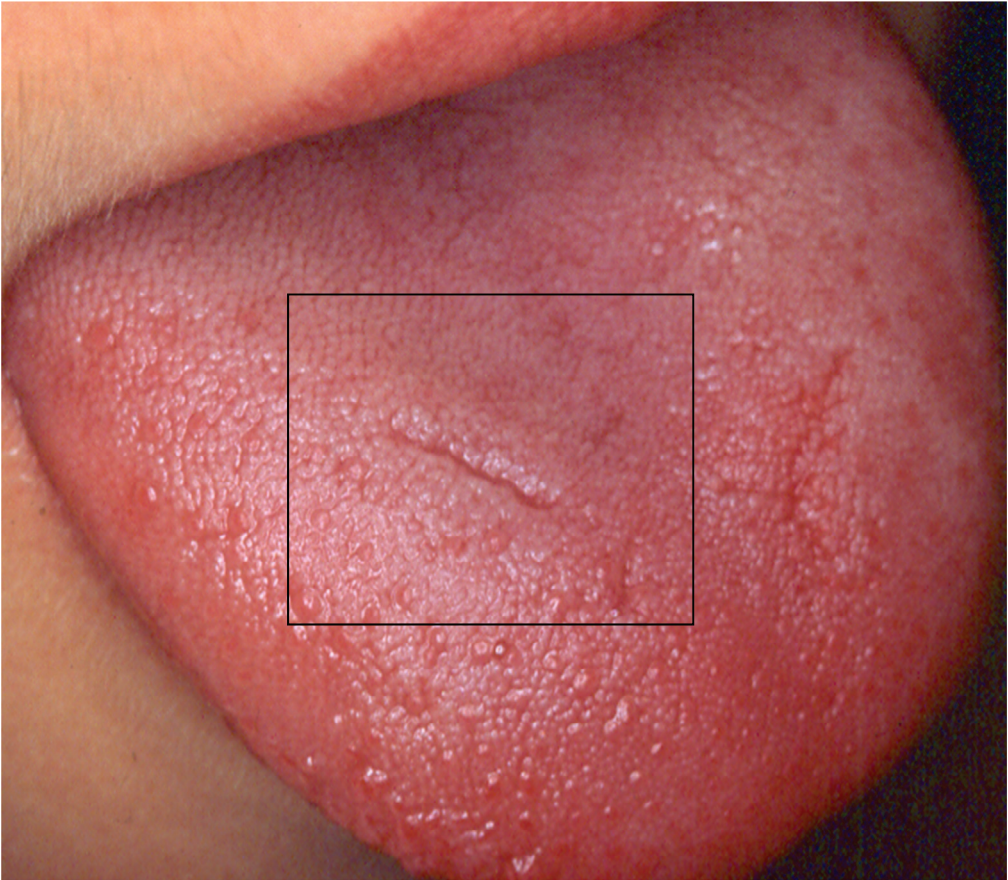


Fig 4.3.4: View of the healed area 6 weeks later. There was no recurrence.

Laser irradiation conditions:

Mode	Continuous
Output power	4 Watts
Focus/ defocus mode	Focus mode
Surgery	Removal by excision or vaporization. Effective protection against exhaust fumes from surgery site.

Healing time needed was approximately two weeks. For this healthy patient, no antibiotics or anti-inflammatory drugs were prescribed during the postoperative peri-

od. Only an antiseptic mouth rinse solution was prescribed to prevent an eventual secondary infection of the wound (to be used three times per day after meals). There was no need for suturing. Carbonization was removed easily using a cotton swab soaked with a Lotagen ® (36% dihydroxydimethyl- diphenylmethane- disulfonic polymerized) solution. The excised tumor was sent for histo-pathological examination.

4.4 Warts

As epithelial benign tumors, warts are rare in the oral environment. The etiologic factor is viral (HPV) with various phenotypes, some of them being the oncogenic virus.

Warts are generally small, white or grey, painless but highly contagious. Histological findings show an epithelial proliferation covered with keratin. Inside the epithelial cells, some viral characteristics may be identified (vacuolization, intra-nuclear inclusions).

The differential diagnosis must be conducted with a special type of squamous carcinoma, exophytic and slightly infiltrative tumor, which look like intense hyperkeratosis (“wart-like”). Warts grow quickly and have a tendency to set up.

From an epidemiological point of view, the lesions of this disease are auto-inoculated and may also be transmitted as a venereal disease.

Definition	Epithelial benign tumor
Macroscopic aspects	White to grey, irregular surface, hyperkeratosis
Etiology	Viral

Clinical case:

Caucasian male, 29 years old, had multiple warts in the mouth and on the lips (Fig. 4.4.1). Local anesthesia (by infiltration under the disease) was used. Great care was taken to evacuate the smoke efficiently during the excision of the lesion by CO₂ laser beam to avoid any viral contamination by the smoke. In addition, the practitioner and the nurses used efficient masks. The warts were widely and deeply removed (2 mm in depth). A security zone of 2 mm around the tumor was also removed (Fig. 4.4.2). The excised tumor was sent for histo- pathological examinations (Fig. 4.4.3). The healing was complete and without recurrence after 2 weeks (Fig. 4.4.4 and Fig. 4.4.5).

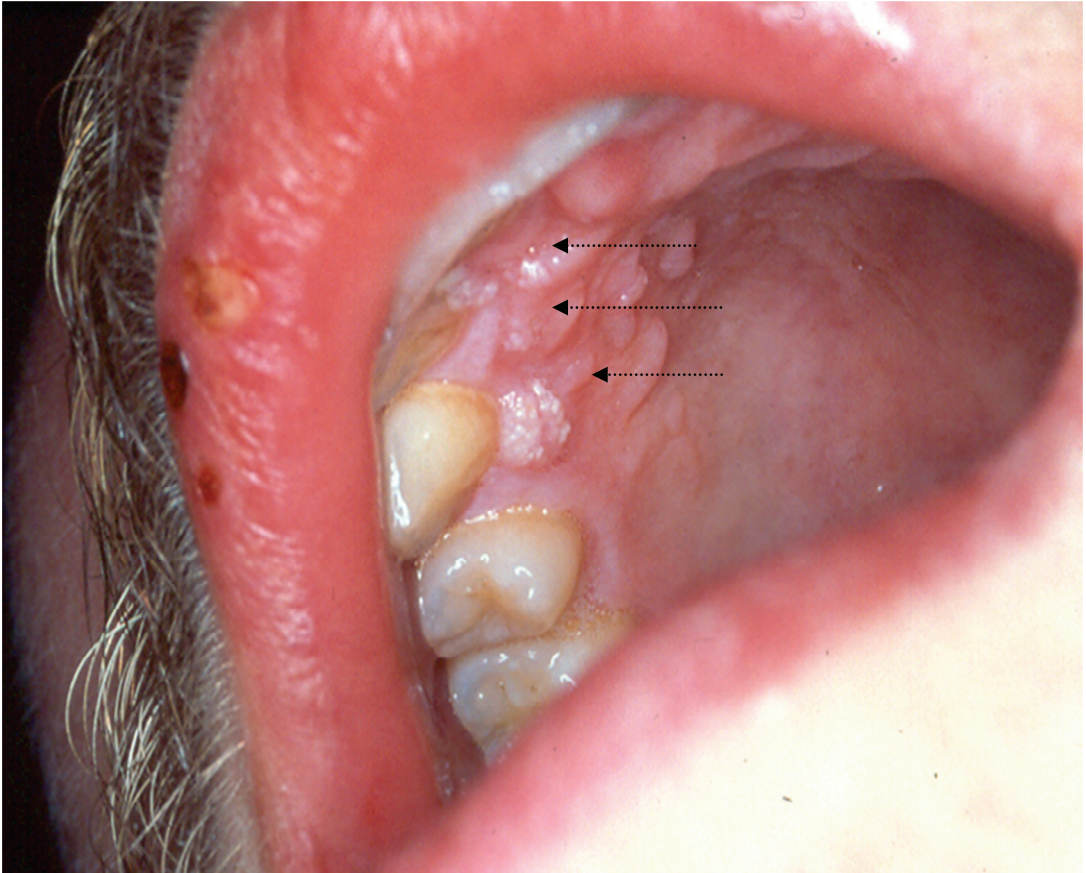


Fig 4.4.1: View of palatal warts.



Fig 4.4.2: Immediate post-operative view. Rare traces of carbonization are still observed. The tumor was removed by excision at its implantation. The excision involved 2 mm from sound marginal epithelial tissues and 2 mm in depth. The hemostatic effect of the CO₂ laser was noted. The carbonization was removed to ensure a rapid and better quality of healing. The excised tumor was sent for histo-pathological examination.

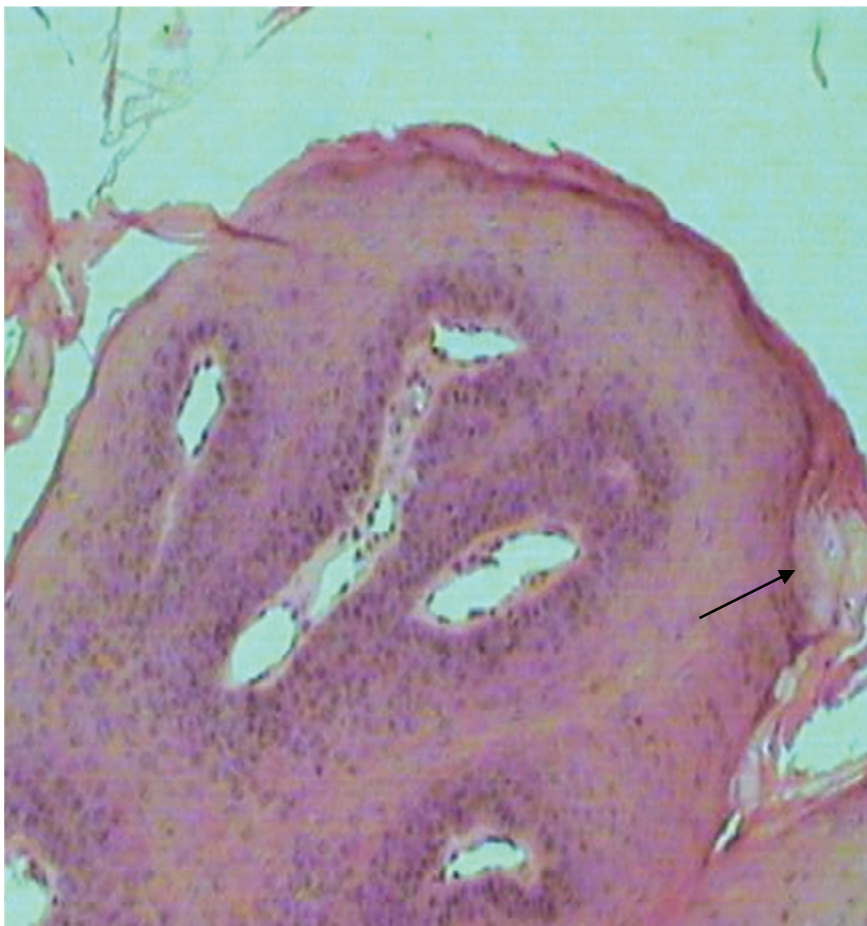


Fig 4.4.3: Microscopic view of a wart tumor. Epithelial proliferations are covered with keratin. The arrow indicates, inside the epithelial cells, some viral characteristics (vacuolization).

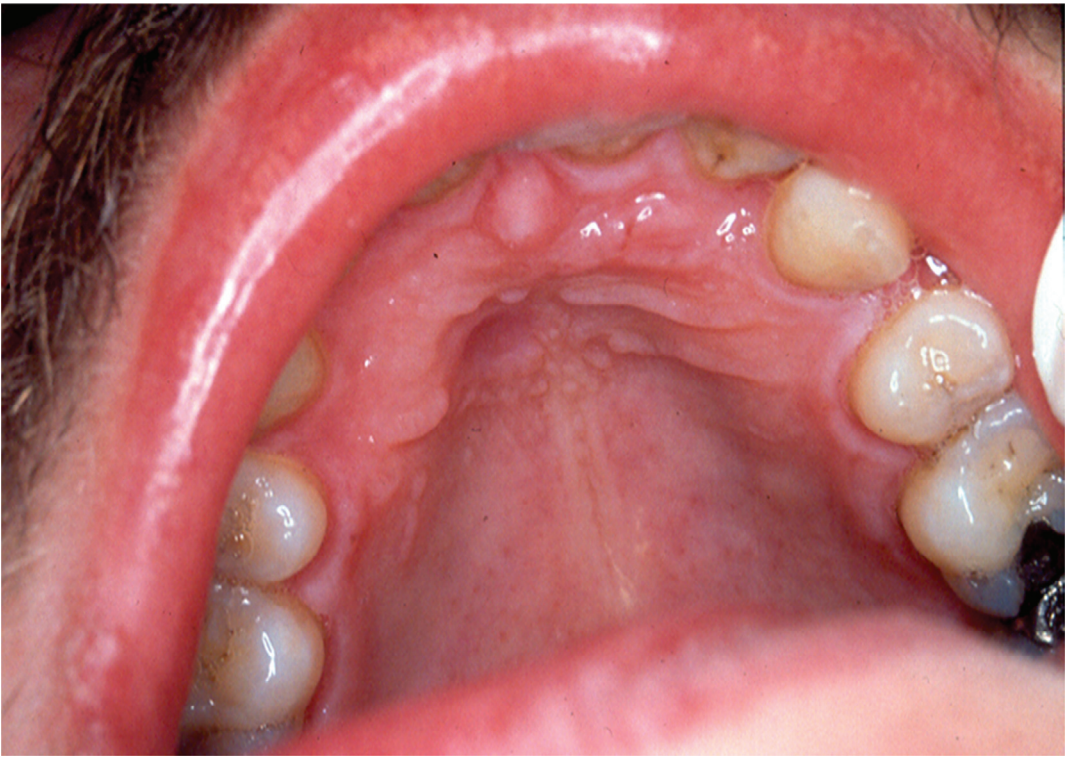


Fig 4.4.4: Macroscopic view after 2 weeks of post-op. The healing was complete without recurrence.



Before

After

Fig 4.4.5: Views of warts before the surgery and at 2 weeks of post-op.

Laser irradiation conditions:

Mode	Continuous
Output power	6 Watts
Focus/defocus mode	Focus mode
Surgery	Removal by excision or vaporization. Effective protection against exhaust fumes from surgery site.

During the post-operative period, an anti-inflammatory, an analgesic, and a disinfecting mouth rinse solution were prescribed. Oral hygiene and prevention recommendations were also given to the patient in order to avoid a second oral in-semination of the virus.

The CO₂ laser is helpful in successfully treating this kind of a tumor because of the beam's great ability to decontaminate. However, great care must be taken to efficiently suck away the smoke caused by the laser's action.

The excision of warts should be done widely and deeply (2 mm from sound marginal epithelial tissues and 2 mm in depth). Carbonization should be removed to ensure rapid and better-quality healing. The excised tumor should be sent for histopathological examination.

In order to avoid a rapid oral reappearance of new warts, it is highly recommended to remove all the detected warts present in the mouth in one session as quickly as possible.

Prevention recommendations should be given to the patient.

4.5 Condylomas

Condyloma is a benign oral tumor associated with HPV infection. This virus is directly responsible for causing other oral diseases including papilloma, verruca vulgaris and the so called focal epithelial hyperplasia (FEH). Unlike many other viruses that infect oral mucosa and induce (only) lyses of the cells penetrated, HPVs produce proliferative changes in these cells that result in both benign and malignant tumors.

Condyloma is a fibrous hyperplastic tumor, which is caused by different HPV-DNA types. A specimen can easily be obtained by scraping the lesion.

Generally asymptomatic, Condyloma may persist, grow or regress spontaneously.

The most common locations are upper lip, lingual frenulum, dorsum of the tongue and lower lip.

From an epidemiological point of view, the lesions of this disease are auto-inoculated and may also be transmitted as a venereal disease.

Definition	Asymptomatic tumorous proliferation
Macroscopic aspects	Tumor with hyperkeratosis aspect,
Etiology	HPV, Traumatic injury

Clinical case

A Caucasian female had a Condyloma on the left posterior area of her mouth (Fig. 4.5.1). A biopsy confirmed the clinical diagnosis. The laser beam was used to excise the tumor involving 1 mm of healthy tissues around the lesion (Fig. 4.5.2). The excised tumor was sent for histo-pathological examination (Fig. 4.5.3). The operated area was healed after 2 weeks (Fig. 4.5.4 and Fig. 4.5.5).

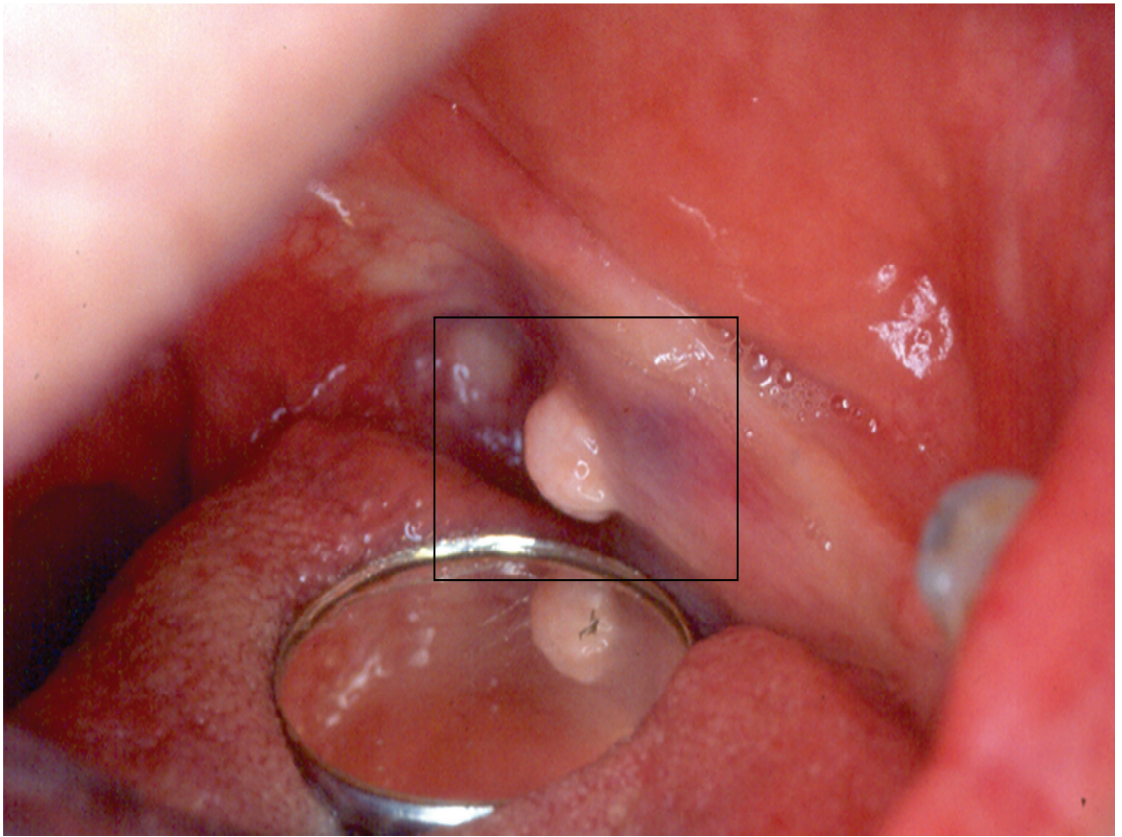


Fig. 4.5.1: View of the condyloma.

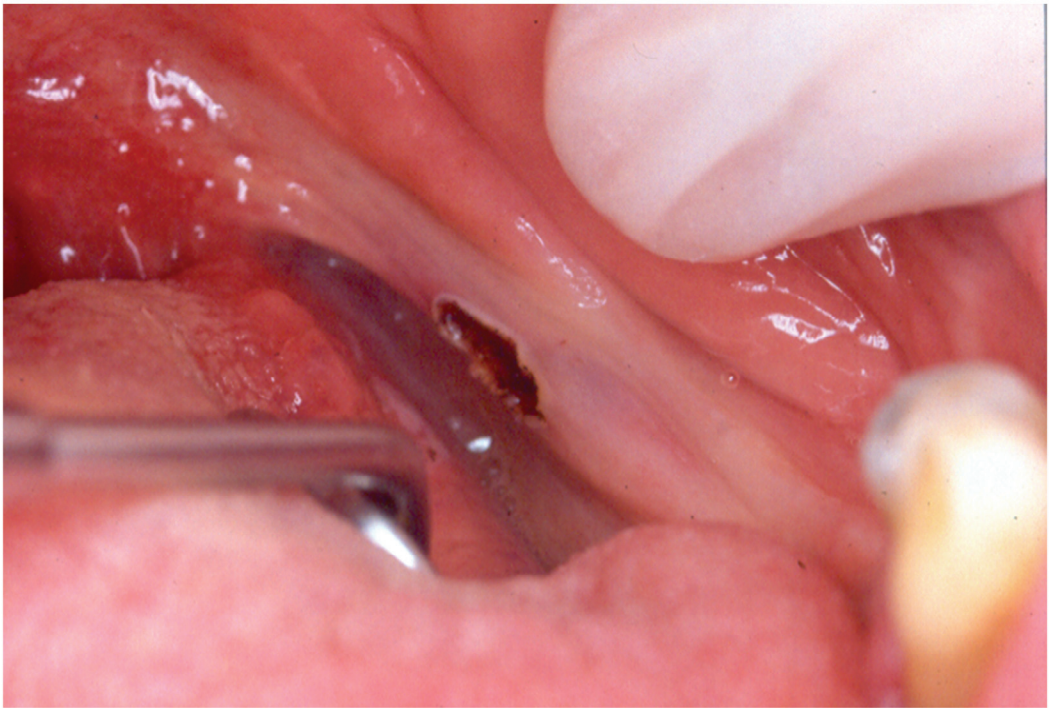


Fig.4.5. 2: View of the surgical site at the end of surgery. The excision involved a large part of surrounding healthy mucosa (removal of 1mm from the surrounding healthy tissues and 1 mm in depth) to ensure a complete ablation of the affected area. The surgery was bloodless. There was no need for suturing. The carbonization was removed and the excised tumor was sent for histo-pathological examination.

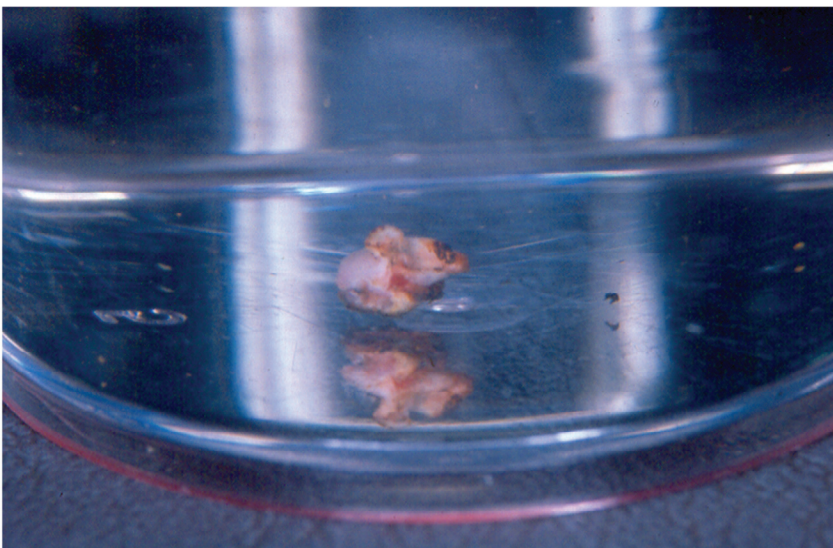


Fig. 4.5.3: View of the excised tumor before sending for histo-pathological examination.

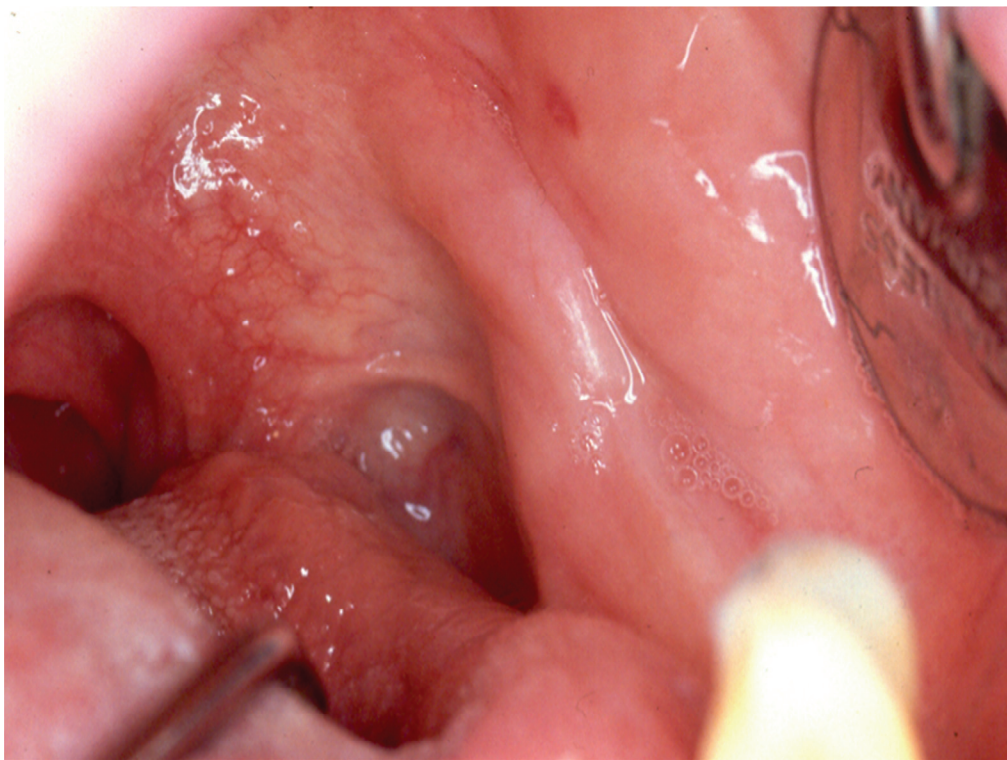
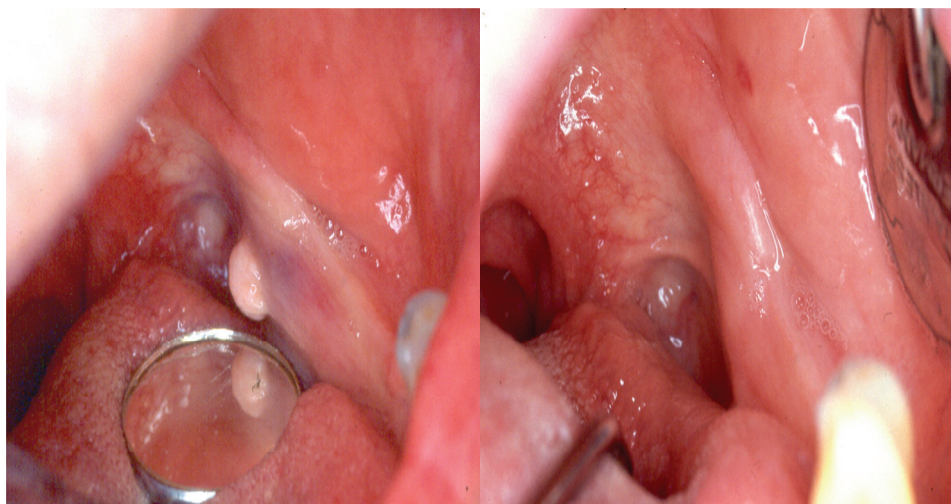


Fig. 4.5.4: View of the healing, 2 weeks after surgery.



Before

After

Fig. 4.5 5: View of the tumor before surgery and the healed area at 2 weeks of post-op

Laser irradiation conditions:

Mode	Continuous
Output power	4 to 6 Watts
Focus/ defocus mode	Focus mode
Surgery	Removal by wide excision. Great care must be taken during smoke evacuation because of the possible virus existence in the smoke.

For this healthy patient (not a risky case), no antibiotics were prescribed for the postoperative period. Only analgesics, an anti-inflammatory, and an antiseptic mouth rinse solution were prescribed (three times per day after meals). There was no need for suturing. Carbonization was removed easily using a cotton swab soaked with a Lotagen ® (36% dihydroxydimethyl- diphenylmethane- disulfonic polymerized) solution. The excised tumor was sent for histo-pathological examination.

4.6 Epulis

The etiology of Epulis is still not understood. In some cases, it may be considered as a granulation tissue derived from the elements of the parodontium. The literature describes different classifications: Granulomatous Epulis, pyogenic granuloma, fibrous Epulis, and giant cell Epulis.

Definition	Tumor close to teeth
Macroscopic aspects	Floppy , red lesion or fibroma-like appearance
Etiology	Not understood, irritation, etc.

Clinical case:

A pregnant female, 26 years old, had an Epulis on the inter-dental papilla between the first molar and the second premolar of the mandible (right side) (Fig. 4.6.1). The patient had bad oral hygiene. The cause of the development of the tumor may have been due to the hormonal disorder (pregnancy) coupled with the bad oral hygiene. The treatment of this kind of a tumor should include educating the patient about oral hygiene. The CO₂ laser beam was used to excise the tumor (Fig. 4.6.2). A total excision of the inter-dental papilla was carried out from the lingual and labial sides. The teeth were protected during surgery with the aim to protect the dental hard tissues against any possible heat damage. The excised tumor was sent for histo-pathological examination (Fig. 4.6.3). The healing was satisfactory (Fig. 4.6.4).

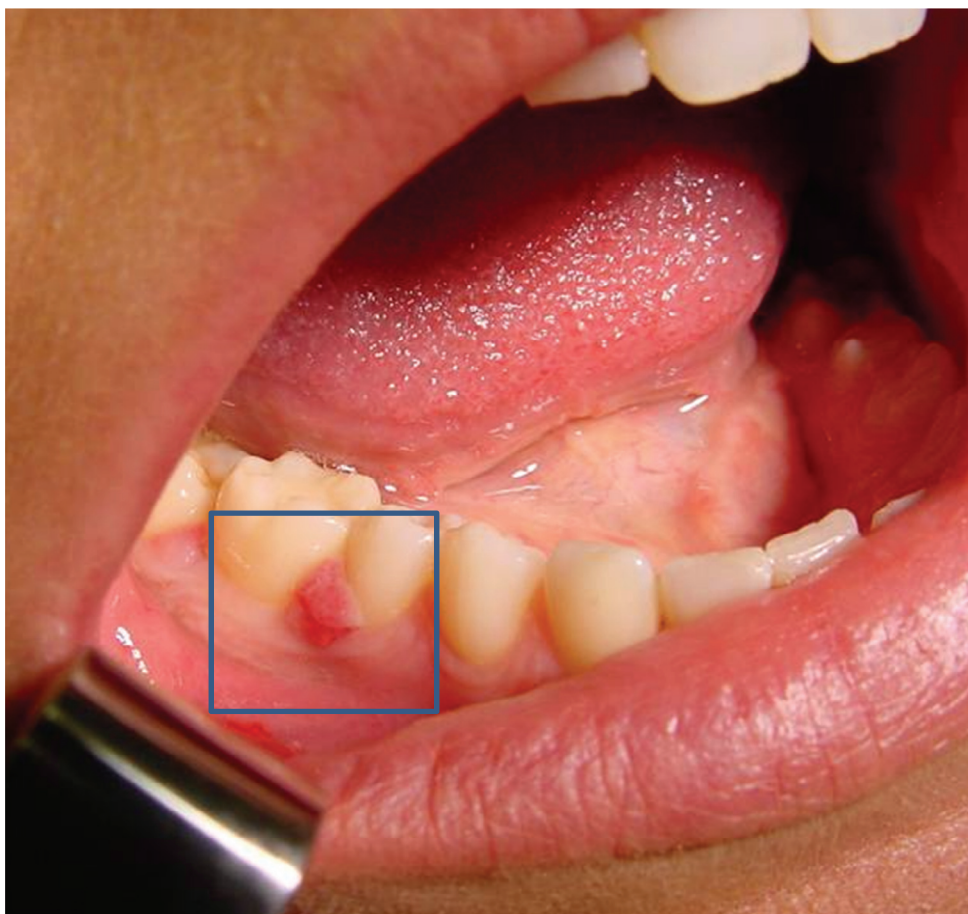


Fig 4.6. 1: Pre-operative view of Epulis.



Fig 4.6.2: The excision of the papilla was done widely (removal of the papilla from labial and lingual side). The adjacent teeth were protected to avoid any possible contact between the laser beam and the dental hard tissues. The carbonization was removed at the end of the surgery. The excised tumor was sent for histo-pathological examination. Only a disinfecting mouth rinse solution was prescribed for the post-operative period. Oral hygiene recommendations were given to the patient.

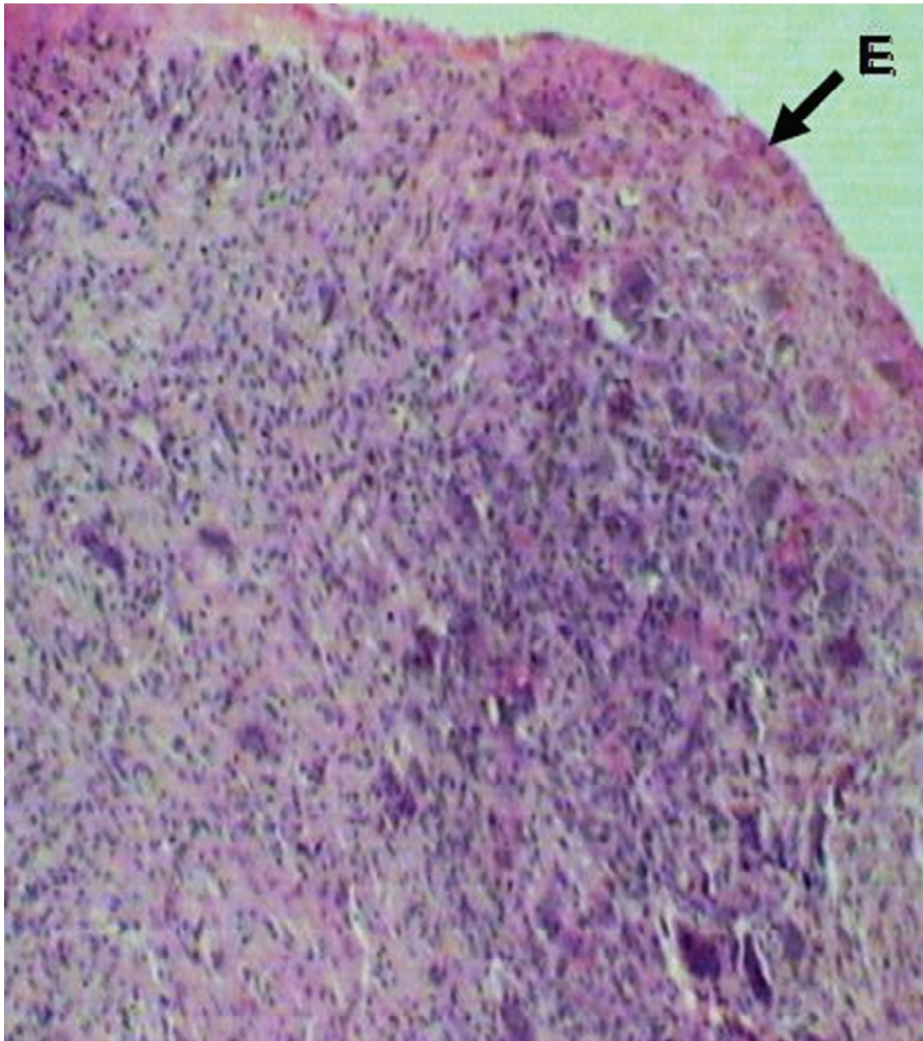


Fig 4.6.3: Microscopic view of Epulis. E: Epithelium covering the connective tissues rich in vessels.



Fig. 4.6.4: View of the healing 10 days after surgery. Future recurrence may be possible if the patient continues to lack oral hygiene.

Laser irradiation conditions:

Mode	Continuous or super-pulsed mode
Output power	2 to 4 Watts
Focus/defocus mode	Focus mode
Surgery	Removal by excision or by vaporization

During the post-operative period, the patient was educated about oral hygiene and an antiseptic mouth rinse was prescribed to prevent secondary infection of the wound (to be used three times per day after meals). The patient was asked to strictly follow the recommendations about oral hygiene in order to avoid any future reappearance of the tumor.

The CO₂ laser is helpful for this tumor surgery because of the beam's capacity to induce the secretion of fibrins (within the first day) and produce a fibrous and resistant healed gum. Great care must be taken to protect the enamel surface of adjacent teeth. The teeth can be easily protected by a metallic dental tool.

4.7 Mucocele

Mucocele is a pseudo-cyst caused by mucus retention from one or several of the minor salivary glands in the lips. The most common etiologic factors are traumatic injuries (biting oneself, twitches, recurrent swelling of the lips by prosthetic origin, or tooth decay). Mucoceles are mainly localized on the lower lips and cheeks.

This benign tumor shows a floppy consistency, is full of mucus with a very thin epithelium, has no indurations, a color ranging from red to bluish, and swells intermittently (on and off).

Conventional treatment is surgery removal, but recurrence may be observed. CO₂ laser treatment seems to be an excellent adapted surgical approach for removal.

Definition	Extravasation of saliva from minor salivary glands
Macroscopic aspects	Swelling, no induration, red to bluish lesion
Etiology	Mucus retention

Clinical case:

Caucasian male, 31 years old, had a mucocele localized in the lower lip with intermittent swelling and unaesthetic aspect of the lip (Fig. 4.7.1). The tumor was painless. Local anesthesia was conducted under the tumor and surrounding the lesion. To prevent any disruption of the mucocele pseudo-cyst, the laser beam must be used carefully in focus mode to excise the tumor and avoid any direct contact with the external layer covering the mucus cistern (6 Watts, focus mode) (Fig. 4.7.2 and Fig. 4.7.3). Immediately after mucocele removal, the CO₂ laser is also used to coagulate the post-surgical exposed tissues to prevent any possible recurrence of the lesion (Fig. 4.7.4). Puncturing the excised mucocele (Fig. 4.7.4) confirmed the existence of mucus in-

side the tumor (Fig. 4.7.5). The excised tissue was sent for histo-pathological examination (Fig. 4.7.6). The healing was satisfactory after 2 weeks of post-op (Fig. 4.7.7).

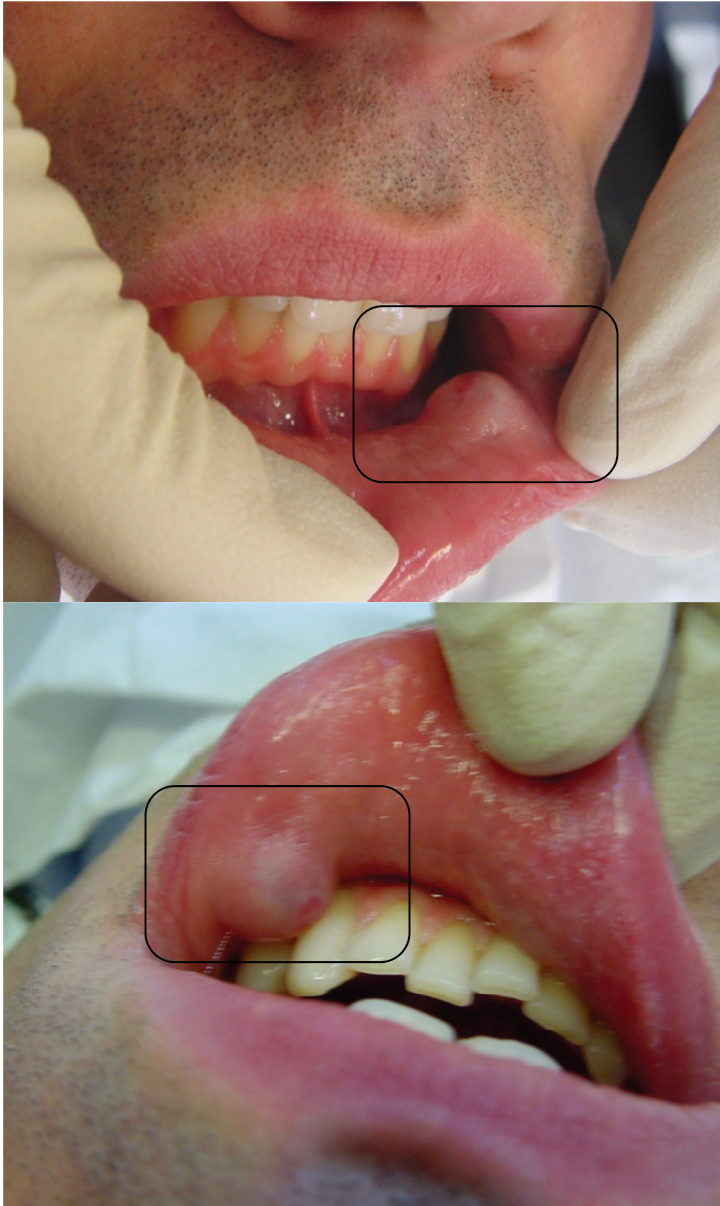


Fig. 4.7.1: Different views of the mucocoele on the lower lip.



Fig. 4.7.2: The mucocoele is excised carefully, avoiding any direct contact with the external layer of the mucus cistern. The field is bloodless due to laser beam action, which is helpful for maintaining easy visual control.



Fig. 4.7.3: View of the surgical site just before the end of the excision of the Mucocoele by CO₂ laser.



Fig. 4.7.4: View of the wound at the end of the excision of the Mucocyst. The carbonized tissues were removed. The surgery was bloodless. There was no need for suturing. The excised tumor was sent for histo-pathological examination.



Fig. 4.7.5: View of the Mucocyst before sending for histo-pathological examination.



Fig. 4.7.6: View of the salivary liquid (Mucus) punctured from the Mucocyst cistern.



Fig 4.7.7: Microscopic view of the Mucocyst containing the salivary liquid (Mucus). C: salivary Cistern.



Fig. 4.7.8: View of the healed area, 2 weeks after surgery.

Laser irradiation conditions:

Mode	Continuous mode or super-pulsed
Output power	3 to 6 Watts
Focus/ defocus mode	• First step (excision): focus mode; 6 watts • Second step (coagulation of the post-surgical exposed tissues): defocus mode; 3 Watts
Surgery	Removal by excision

Antibiotics, analgesics, an anti-inflammatory, and an antiseptic mouth-rinse solution were prescribed for the postoperative period. There was no need for suturing. Carbonization was removed easily using a cotton swab soaked with a Lotagen ® (36% dihydroxydimethyl- diphenylmethane- disulfonic polymerized) solution. The excised tumor was sent for histo-pathological examination.

Note: the destruction of the external layer of the mucus cistern will make the excision of the tumor very difficult and could lead to a failure of the surgery, as well as a recurrence of the tumor.

4.8 Pyogenic Granulomas, Peripheral giant cell granulomas (PGCG), Choristomas, and lipomas

The pyogenic granuloma represents an exuberant tissue. The etiology can incriminate a response to local irritation or trauma. Its surface may be smooth or lobulated, and it may appear in different sizes (a few millimeters to several centimeters). Pyogenic granuloma of the oral cavity is known to involve the gingival mucosa (75% of all cases). Rarely, it may appear extra-gingivally.

For Pyogenic Granulomas, Choristomas, and Lipomas, the treatment and laser-assisted ablation of these tumors are similar to those followed in the section about Fibroma. The excision is simple and recurrences are rare.

Concerning the treatment of Peripheral giant cell granulomas (PGCG): the treatment and laser-assisted ablation of these tumors are similar to those followed in the section about Epulis, and includes a large ablation of healthy tissues ($\pm$ 2 to 3 mm).

HYPERKERATOSIS

Due to the potential risks of recurrence involved in the treatment for hyperkeratosis, some precautions must be observed. The patient's medical history must be well known in order to identify if he or she is at high risk. The underlying risk factors (tobacco use, alcohol use, conjunction of the two factors, a previous HPV infection, irritation, salivary situation, etc.), as well as the patient's general health status and medications taken are valuable pieces of knowledge.

Examination of the patient should include extra-oral and intra-oral examinations. Inspection of the oral mucosa includes lips, cheeks, palate, tongue, alveolar processes, and the floor of the mouth. However, while inspection is certainly important, it is insufficient. A bimanual palpation of the lesion (if indurations) and some anatomic regions (tongue, floor of the mouth, regional lymphatic glands), as well as observation of the tongue when pulled outward are essential to complete the clinical examination. *A biopsy and histo-pathological examination remain the only means to confirm the clinical diagnosis—they are mandatory before any therapy decision.*

All necessary information collected during the examination (size of the lesion, consistency, color, aspect, etc.) must be recorded and photo documented.

Early-stage detection of pre-cancerous lesions is of great importance because cancer often manifests symptoms late, sometimes too late, and starts out as a non-tender tumor. It is also necessary to respect the following rule: in case of suspicion and when the clinical diagnosis is uncertain, the patient must be sent “untouched” to a specialized team (oncologists).

5.1 Leukoplakia

Leukoplakia is defined as a predominantly white lesion of the oral mucosa that cannot be scraped off.

The WHO (World Health Organization) classification reveals three types of leukoplakia:

- Homogeneous leukoplakia: a mainly white, flat, and thin lesion with smooth, wrinkled, or corrugated surfaces;
- Non homogeneous leukoplakia: white or white and red, irregular, flat, nodular (slightly elevated, rounded) or exophytic (irregular, blunt or sharp projections);

- Erythroplakia: rare, red areas that cannot be diagnosed as any other disease. When suspected, the patient must be sent to a specialist as soon as possible.

Leukoplakia is mainly asymptomatic without regional lymphatic glands disorder and may occur either as a single, localised change of the oral mucosa or as diffuse and multiple lesions. Any oral site may be affected.

A histo-pathological examination (biopsy) is mandatory prior to any laser therapy in order to avoid an inadequate treatment of manifest carcinomas. After each CO₂ laser surgery, the excised tissue must be referred again for histo-pathological examination in order to identify any signs of malignancy. In the case of positive results, the patient must be referred immediately to a specialist.

The CO₂ laser is helpful in the treatment of leukoplakia, and has a high percentage of success. The removal of the lesion must involve a security zone of 2 mm from surrounding healthy tissue (around the lesion). The depth of the excised area must exceed 1 mm in order to remove the epithelium and a part of the deeper tissues.

Definition	Epithelial lesion, predominantly white, impossible to scrape off
Macroscopic aspects	Homogeneous: white, flat, thin, smooth; Non-homogeneous: white, white-red, irregular, nodular or exophytic;
Etiology	Unknown or underlying factors

Clinical cases:

Case 1: A Caucasian female, 68 years old, developed a leukoplakia under her acrylic denture (Fig. 5.1.1). The diagnosis of the leukoplakia lesion was confirmed by histo-pathological examination of a pre-op biopsy. Before surgery, a line demarcating the future excised area was made (Fig. 5.1.2). The total ablation of the lesion was completed in one session. The lesion was largely and deeply removed (2 mm around and 1 mm in the depth) (Fig. 5.1.3). The carbonization was removed at the end of the surgery. Figure 5.1.4 shows the schema of the excised area (Fig. 5.1.4). The excised tissues were sent for histo-pathological examinations (Fig. 5.1.5). An antibiotic, anti-inflammatory, analgesic, and a disinfecting mouth rinse solution were prescribed for the post-op period. The patient could wear his denture only during periods of eating. The acrylic of the intrados of the denture corresponding to the surgical site was smoothly removed to avoid any direct contact between the wound and the denture

during mastication. A new denture can be made or a permanent relining of the original denture can be done after a period of 4 weeks of post-op. The healing in the case was satisfactory (Fig. 5.1.6 and Fig. 5.1.7).



Fig. 5.1.1: View of Leukoplakia lesions developed on the maxillary ridge under an acrylic denture. The irritation of the lesion by the denture may increase the probability of malignant transformation.

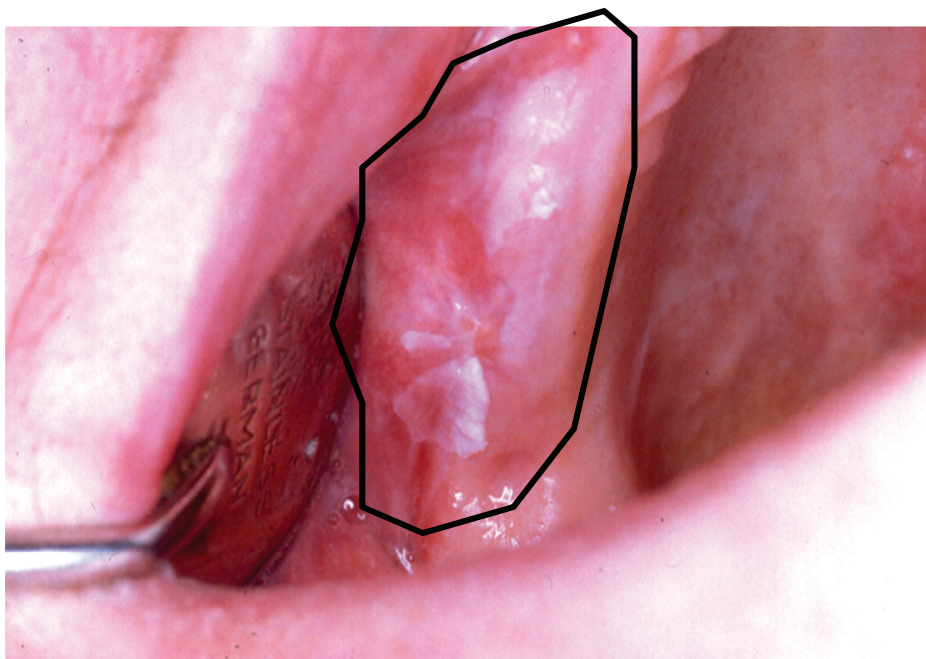
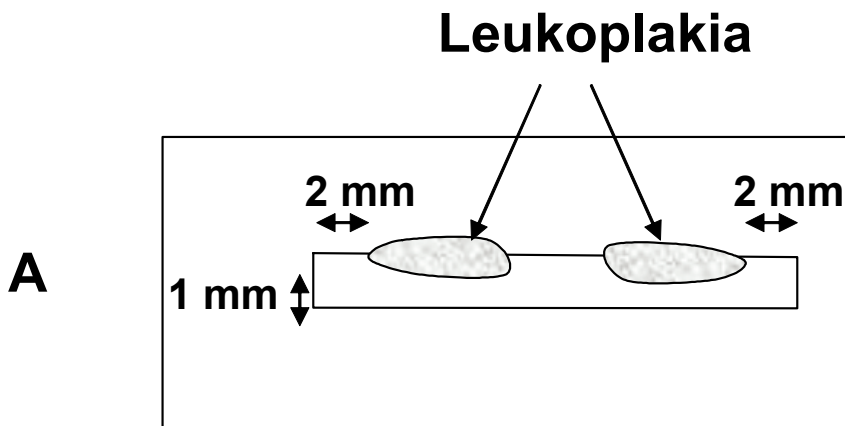


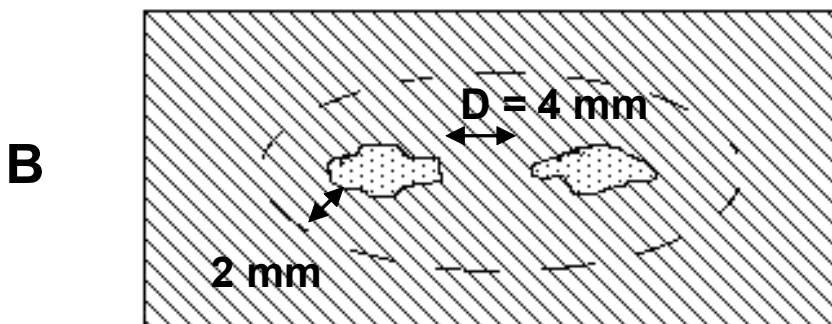
Fig. 5.1.2: The Laser beam demarcates the limit of the ablated tissue before starting the excision of the lesion (see schema).



Fig. 5.1.3: Partial view of the leukoplakia removal during surgery. The rest of the lesion will be removed in the same session. During the surgery, a security zone of 2 mm from the surrounding healthy tissue around the lesion will be removed. The depth of the ablated area will be around 1 mm in order to remove the epithelium and a part of the deeper connective tissues.



Cross section view



Direct view

Fig 5.1.4:

A) Cross section showing the directives of ablation of a Leukoplakia: 2 mm of surrounding healthy tissues and 1 mm in depth.

B) If the distance between 2 lesions is $\leq 4 \text{ mm}$, both areas will be considered as 1 larger lesion and treated globally as schematized.

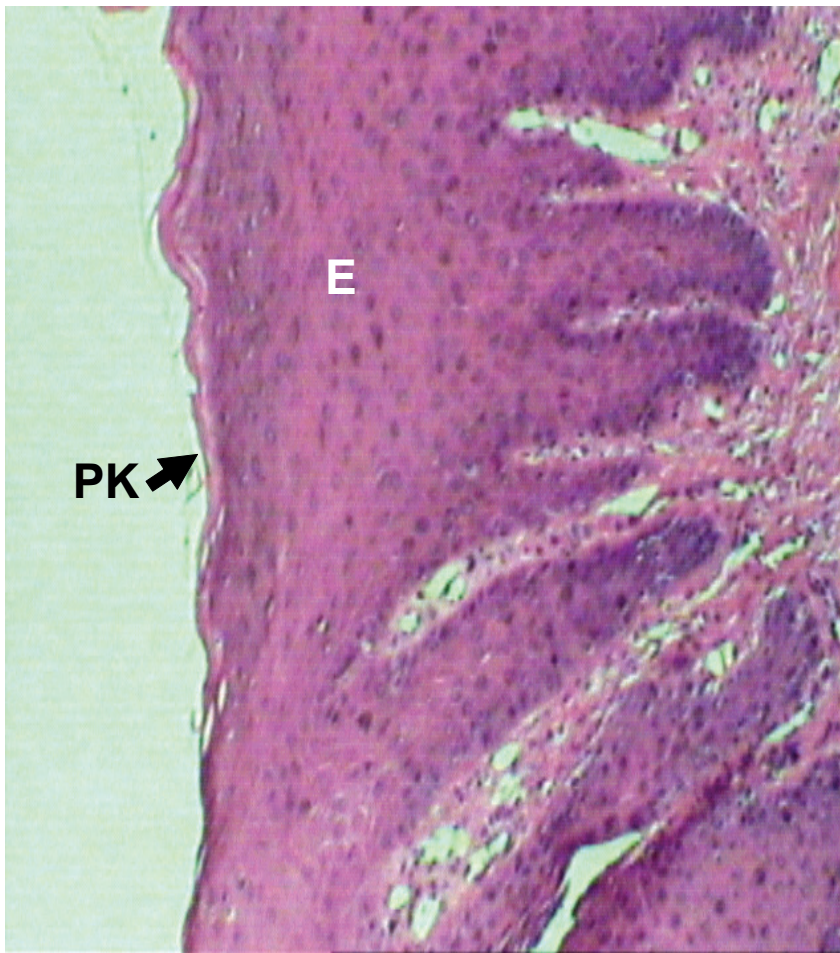


Fig. 5.1.5: View of the Leukoplakia. E: Hyperplastic Epithelium; PK: Parakeratosis layer.



Fig. 5.1.6: View of the healed area one month after surgery.



Before

After

Fig. 5.1.7: View of the Leukoplakia before surgery and the healed site after one month of post-op.

Laser irradiation conditions:

Mode	Continuous or super-pulsed
Output power	4- 12 Watts
Focus/ defocus mode	Focus mode
Surgery	Removal by excision

The patient did not wear her upper denture during the first 2 weeks in post-op period, except for during eating times. Antibiotics, analgesics and anti-inflammatory drugs including an antiseptic mouth rinse solution were prescribed.

To conclude:

- Biopsy before surgery is necessary to confirm the clinical diagnosis,
- A wide range of excision around the lesion is necessary. The removal of the lesion must involve a security zone of 2 mm from surrounding healthy tissue. The depth of the excised area should exceed 1 mm in order to remove the epithelium and a part of the deeper tissues,
- A follow-up period of 2 years minimum is necessary for this diagnosis.

5.2 Lichen Planus

Considered to be a precancerous disease, the malignancy incidence for lichen planus ranges from 0.5 to 12.5%. The WHO classification discerns a varied pattern from which six main types can be described:

- Papular, reticular, and plaque are white lesions
- Atrophic, ulcerous, and bullous are red lesions.

More than one type may be observed simultaneously on the oral mucosa.

Clinically the initial lesion is white and papular, growing to be coalescent (plaque) and white-grey with small relief. Oral lesions are generally observed on both sides of the cheeks and more rarely on the tongue and lips. Typical lesions on the cheeks show a pseudo triangular design and are mainly bilateral.

Definition	Epithelial dysplasia, predominantly white lesions, impossible to be scraped off
Macroscopic aspects	White to grey, irregular, network- like aspect
Etiology	Auto-immune pathology coupled to other factors

The etiology is considered to be auto-immune disease coupled with other factors (psychosomatic factors, stress, drugs, etc.)

Each time a local factor is suspected or identified, a local treatment must be started: careful mouth hygiene procedures, tooth fillings polishing or rebuilding, including a possible change of materials (ceramic versus dental amalgams, prosthetic crowns, etc.) Allergy tests may represent an appropriate complement to identify a local etiologic factor. The patient's saliva quality should also be evaluated.

In all cases, a biopsy should be done to confirm the clinical diagnosis. When malignancy is suspected, the patient must be immediately referred to specialists in oncology.

CO₂ laser surgery by excision of the lesion cannot be considered the principle treatment for this kind of disease because of the systemic etiology (auto-immune). It has been demonstrated that the CO₂ laser provokes a bio-modulation effect in lichen planus-affected tissues. The irradiation of the lesion provokes an immediate reduction of the lymphocyte's attack of the affected epithelium.

Laser surgery may be conducted in very specific cases: removal of a limited hypersensitive area of the lichen planus (e.g., a burning or painful limited area), or to treat a local erosive and ulcerous area. The laser surgery treatment alone cannot be considered the treatment of choice of lichen planus. Further, it cannot be used to treat the entire lesion.

Clinical case:

A North African male, 62 years old, had bilateral lichen planus lesions on his cheeks. The diagnosis of the lesion on the left cheek was confirmed by histo-pathological examination (biopsy) before any surgery. The patient followed-up for 5 years. The Lichen planus developed on the right cheek was an apparition of an erosive area followed by a malignant transformation (Fig. 5.2.1). The right side received a deep and entire ablation of the cheek carcinoma followed by a skin graft from the buttocks (Fig. 5.2.2). Two years after the graft surgery on the right cheek, an erosive area appeared on the left cheek without any cellular dysplasia or malignant transformation (Fig. 5.2.3). Based on the history of the patient, it was decided to remove the erosive area on right cheek. The lesion was largely and deeply removed (3 mm around and 2 mm in the depth) (Fig. 6.2.4). The carbonization was removed at the end of the surgery (Fig. 5.2.5). The excised tissues were sent for histo-pathological examinations. An antibiotic, anti-inflammatory, analgesic, and a disinfecting mouth rinse solution were prescribed for the post-op period. There was no recurrence during the 5 years of follow up. The healing was satisfactory after one month into the post-op period (Fig. 5.2.6 and Fig. 5.2.7).



Fig. 5.2.1: View of the carcinoma on the right cheek of the patient.



Fig. 5.2.2: View of the skin graft at one year after the large excision of the carcinoma on the right cheek of the patient.



Fig. 5.2.3: View of the erosive area of Lichen planus lesion developed in the cheek (left side of the same patient).

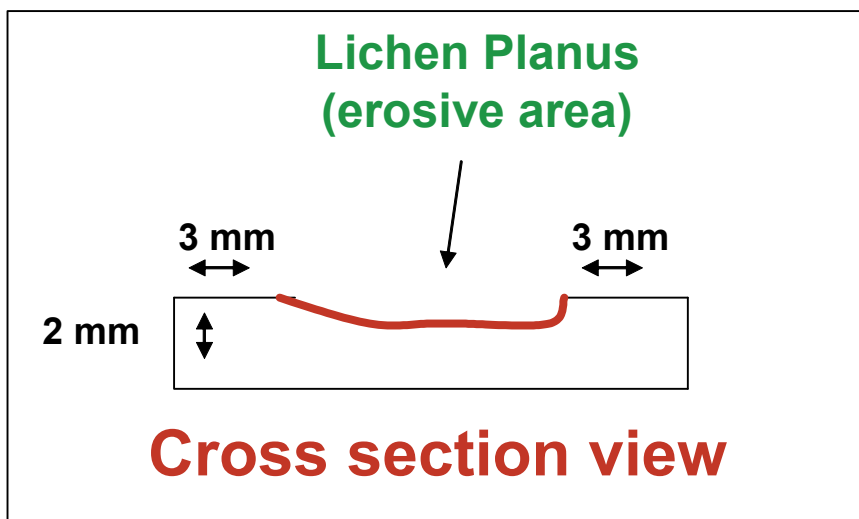


Fig 5.2.4: Schema of a cross section showing the directives of ablation of an erosive area of a Lichen planus: 3 mm of surrounding healthy tissues and 2 mm in the depth.

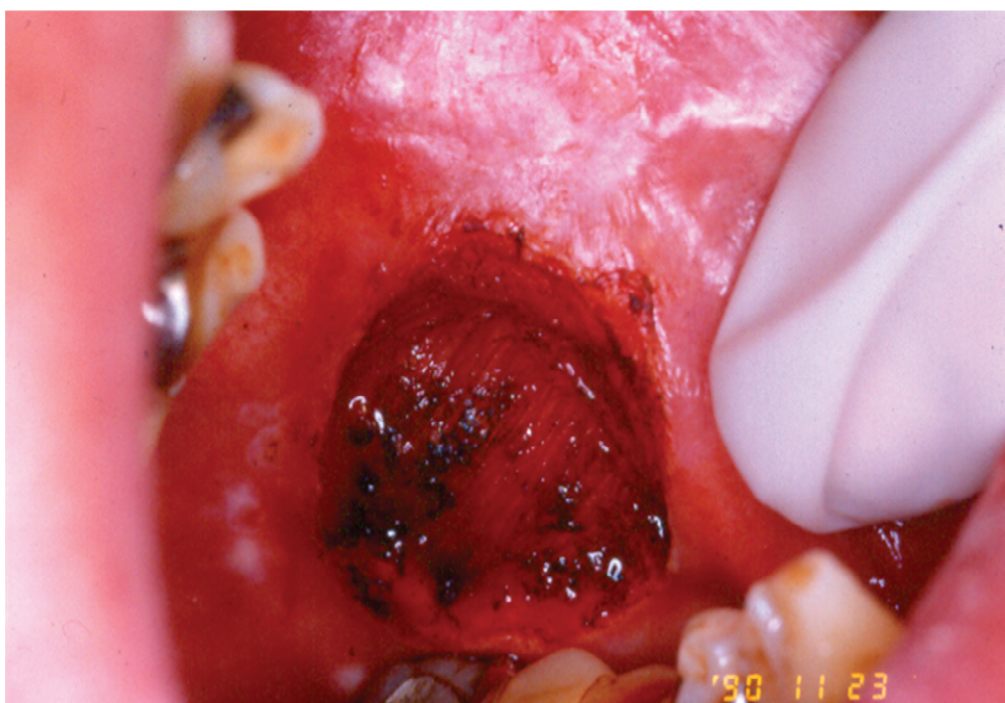


Fig. 5.2.5: View of surgical site at the end of surgery. The removal of the lesion must involve a security zone of 3 mm from surrounding healthy tissue. The depth of the excised area was ± 2 mm in order to remove the erosive epithelium and an important part of the deeper tissues.

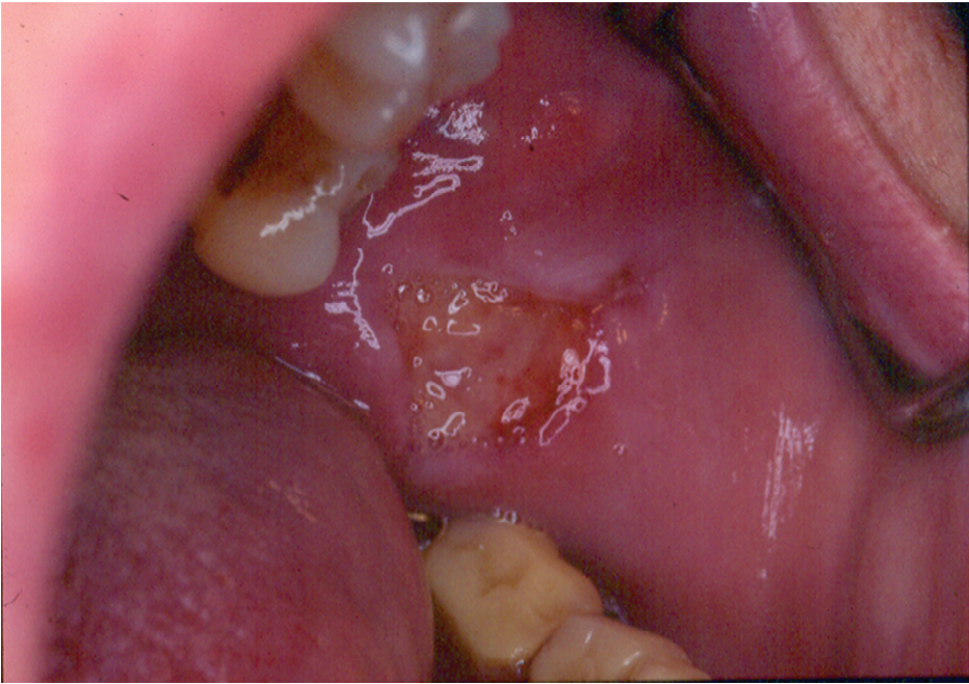


Fig. 5.2.6: View of the wound at 2 weeks after surgery. The secreted fibrin is still covering the site.

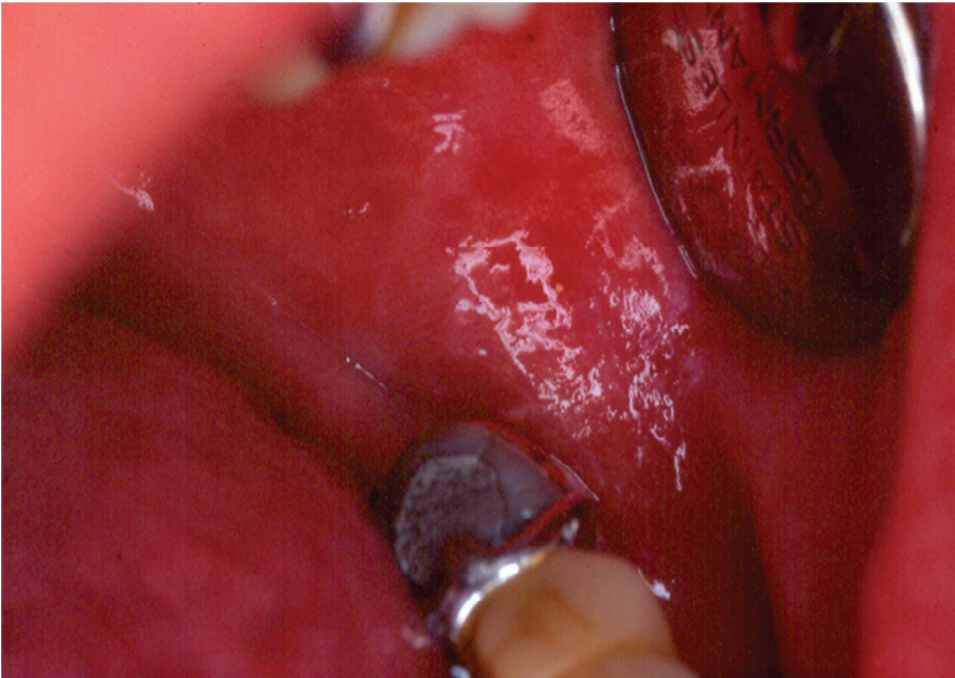


Fig. 5.2.7: View of the healing at 2 months after surgery.

Laser irradiation conditions:

Mode	Continuous or super-pulsed
Output power	6 – 12 Watts
Focus/defocus mode	Focus mode
Surgery	Removal by excision

To conclude: For the treatment of the erosive or ulcerous lesion of Lichen planus, we advise to respect the following steps:

- Biopsy.
- Use a wide range of excision, and re-send the excised tissues for histopathological examination.
- Follow-up for a minimum of 2 years.

VASCULAR LESIONS (ANGIOMAS)

6.1 Capillary Hemangioma (blood pearl)

Trauma and injury to the lips require immediate professional attention to determine the adapted procedures to follow.

The most common etiology of Capillary Hemangioma (blood pearl) is traumatic. The incidence of these lesions increases with age, especially for women.

Systemic factors are not involved as the main factor in those blood pearls, but may represent co-factors (coagulopathies, vascular disorders) that do not disturb the treatment plan.

Definition	Capillary, blood cistern, benign tumor
Macroscopic aspects	Bluish, purple, or red mass.
Etiology	Accidental injury coupled or not with local predisposition factors
Differential diagnosis	Cavernous Hemangioma: the history of the appearance of the tumor is helpful for the diagnosis.

Clinical case 1:

A Caucasian female, 48 years old, had a capillary Hemangioma on the lower lip (Fig. 6.1.1). The tumor appeared after a traumatic injury of the lip. The laser was used first to dry the blood cavity and a second time to coagulate the inner surface to avoid any post-operative bleeding and coagulate and close the blood vessels draining the cistern (Fig. 6.1.2). In general, this type of tumor can be removed by excision or vaporization by heat generated to dry the blood cavity. During surgery, incision of the layer covering the blood cistern must be avoided in order to avoid any bleeding risk. A disinfecting mouth rinse solution was the only treatment prescribed for the post-operative period. The healing aspect of the lip was excellent, without any scar formation or any loss in the lip symmetry and design (Fig. 6.1.3). Lasers are typically helpful in treating this kind of a tumor.



Fig. 6.1.1: View of the capillary Hemangioma on the lower lip.



Fig 6.1.2: After a local anesthesia, a laser beam was used in defocus mode to first vaporize the blood cavity and then coagulate the inner surface the second time. A soft pressure on the wound can be used in order to verify and detect an existing bleeding source in the cavity. In case of any appearance of bleeding, the laser beam will be used again in defocus mode to close up the opened blood vessel. In general, the tumor can be removed by excision or vaporization by heat generated to dry the blood cavity. During surgery, incision of the layer covering the blood cittern must be avoided in order to avoid any bleeding risk. It is advised to keep the carbonization in the cavity in order to decrease the risk of any future bleeding during the post-op period.



Fig. 6.1.3: View of the healed lip. The aesthetic aspect of the lip is satisfactory.

Clinical case 2:

A Caucasian female, 56 years old, had a capillary hemangioma on the upper lip (Fig. 5.1.4). The tumor appeared because of a traumatic injury. The laser was first used to dry the blood cavity, and a second time to coagulate the inner surface to avoid any post-operative bleeding. A disinfecting mouth rinse solution was the only treatment prescribed for the post-operative period. The healing aspect of the lip was excellent without any scar formation or any loss in the lip symmetry and design. Lasers are typically helpful in treating this kind of a tumor.



Fig. 6.1.4: View of the capillary Hemangioma on the upper lip.



Fig 6.1.5: After a local anesthesia, a laser beam was used in defocus mode to first vaporize the blood cavity and then coagulate the inner surface the second time. A soft pressure on the wound can be used in order to verify and detect an existing bleeding source in the cavity. In case of any appearance of bleeding, the laser beam will be used again in defocus mode to close up the opened blood vessel. It is advised to keep the carbonization in the cavity in order to decrease the risk of any future bleeding during the post-op period. Only a disinfecting mouth rinse solution was prescribed for the post-operative period. In general, the tumor can be removed by excision or vaporization by heat generated to dry the blood cavity. During surgery, incision of the layer covering the blood cittern must be avoided in order to avoid any bleeding risk.



Fig. 6.1.6: View of the healed lip. The aesthetic aspect of the lip is satisfactory.

Laser irradiation conditions:

Mode	Continuous
Output power	2 Watts
Focus/ defocus mode	Defocus mode
Surgery	Excision in case of small tumor Vaporization by heat generated to dry the blood cavity. During surgery, incision of the layer covering the blood cit- tern must be avoided

Great care should be taken during the ablation of this kind of a tumor because of the risk of bleeding and the possible unaesthetic aspect of the healed lip (loss in the symmetry of the lip design). Only an expert in oral laser surgery can perform this type of surgery.

6.2 Hemangiomas

This is a benign tumor composed of blood vessels. Hemangiomas are often present at birth, and may appear in the early years of life.

Bluish, purple, or red, these lesions can involve the oral bone, tongue, labial mucosa, cheeks, palate, and gingival tissue.

The classification of hemangiomas is based on their histo-pathological appearance as capillary, cavernous, or mixed. Clinical diagnosis is based on appearance and symptoms that are highly dependent on the haemo-dynamic flow inside the tumor. This haemo-dynamic flow explains why the color changes when pressure is applied.

These tumors may progress slowly, involving extensive portions of superficial and deep blood vessels.

Before treatment, even though bone involvement is very uncommon, it is highly recommended to look for any possible endosseous extension (tomodensitometric examination), as well as to verify that the patient has no coagulation factor abnormalities.

Hemangiomas treatment is always clinically difficult because the lesions may pose serious bleeding risks. The use of the CO₂ laser represents a significant breakthrough in the management of this pathology because of its hemostatic potential.

In order to determine the dimensions of the disease, different examinations (RMI, tomodensitometric examination, etc.) must be accomplished before any surgery decision because of the high bleeding potential in Hemangiomas removal.

An expert in oral laser surgery can use the laser beam to excise a small tumor (smaller than 10 mm). *This kind of surgery must be done by a specialist.* Great care must be taken in order to avoid the high risk of bleeding.

Definition	Capillary, cavernous, or mixed mass (vascular benign tumor)
Macroscopic aspects	Bluish, purple, or red mass
Etiology	Developmental and neoplastic probable origin

Clinical case:

A Caucasian female, 28 years old, had a hemangioma on her right cheek (Fig. 6.2.1). The tumor was discovered at the early age of 3 years. The laser was first used to excise the tumor and a second time to coagulate the inner surface to avoid any post-operative bleeding (Fig. 6.2.2). The excised tumor was sent for histo-pathological examination (Fig. 6.2.3). During surgery, incision of the layer covering the blood cistern must be avoided in order to avoid any bleeding risk. The carbonization due to the action of CO₂ laser is kept in the wound cavity in order to decrease the risk of post-op bleeding. A disinfecting mouth rinse solution was prescribed for the post-operative period. The healing aspect of the cheek is excellent, without any scar formation (Fig. 6.2.4).

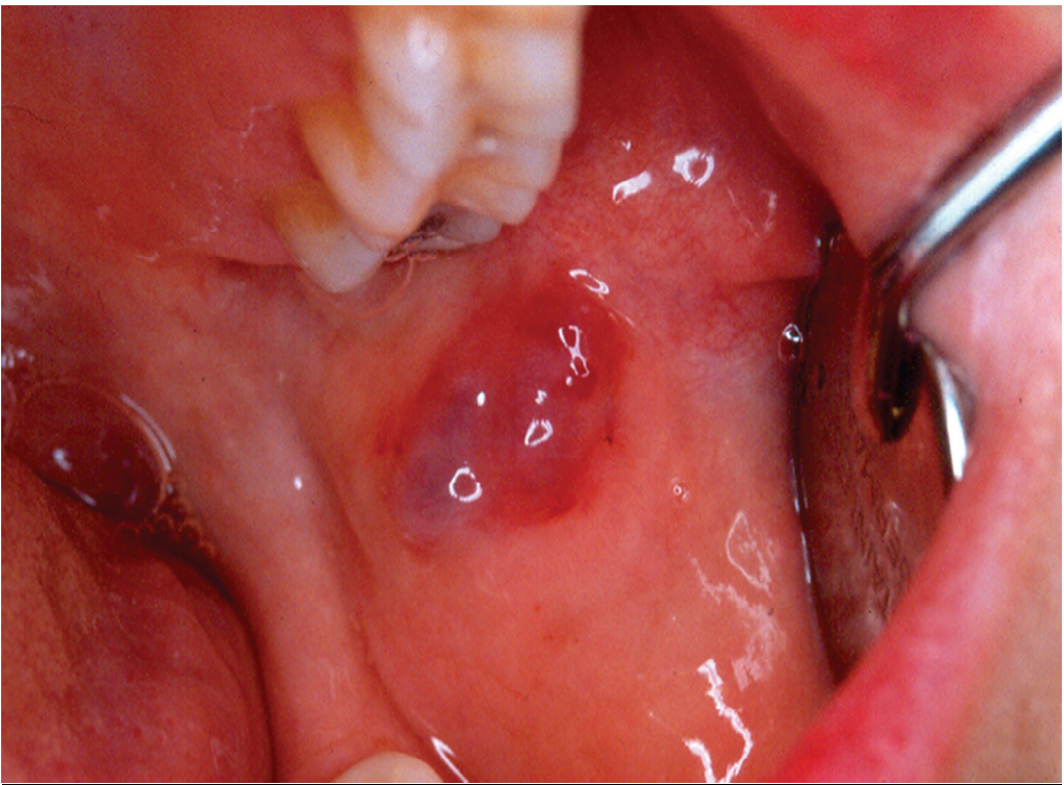


Fig. 6.2.1: View of the cheek Hemangioma.



Fig 6.2.2: After local anesthesia, a laser beam was used to excise the tumor and coagulate the inner surface. A soft pressure on the wound can be used in order to verify and detect an existing bleeding source in the cavity. In case of any appearance of bleeding, the laser beam will be used again in defocus mode to close up the opened blood vessel. In general, the tumor is removed by excision. During surgery, incision of the layer covering the blood cistern must be avoided in order to avoid any bleeding risk. It is advised to keep the carbonization in the cavity in order to decrease the risk of any future bleeding during the post-op period. Only a disinfecting mouth rinse solution was prescribed.



Fig 6.2.3: Panoramic view of the Hemangioma. E: Epithelium; V: Blood vessels.

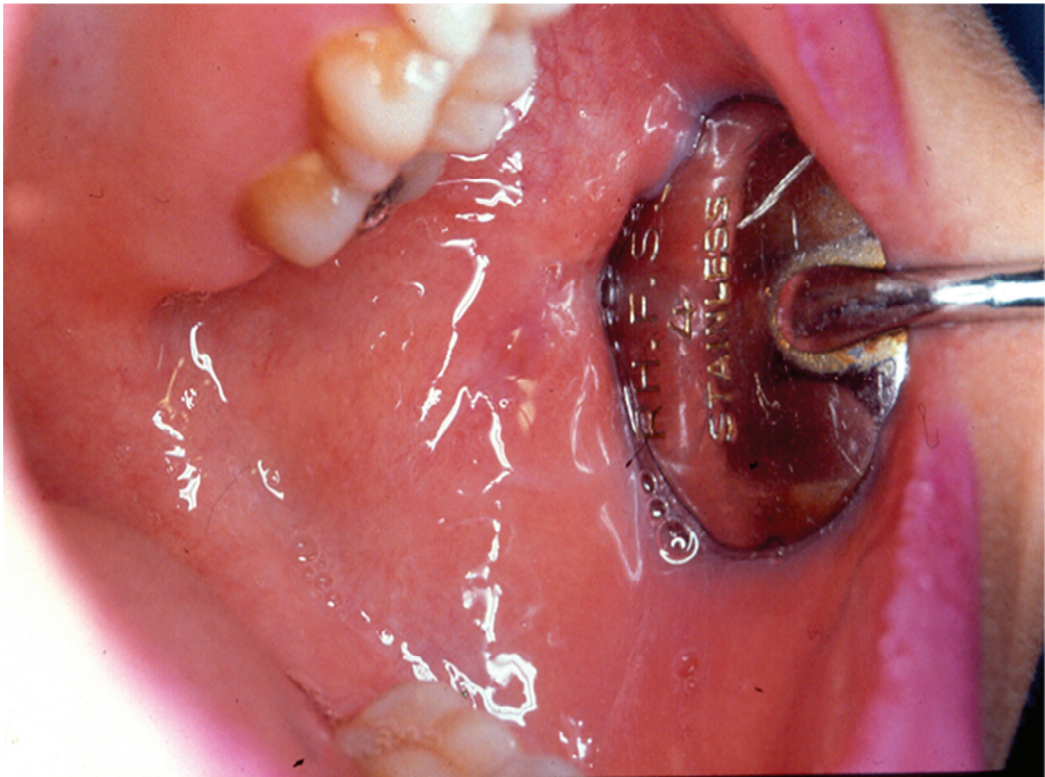


Fig. 6.2.4: View of the healed cheek. The aesthetic aspect of the cheek is satisfactory.

Laser irradiation conditions:

Mode	Continuous
Output power	2 Watts
Focus/defocus mode	Defocus mode for vaporization Focus mode for excision
Surgery	Excision if small tumor Vaporization by heat generated to dry the blood cavity. During surgery, the incision of the layer covering the blood cittern must be avoided

Great care should be taken during the ablation of this kind of a tumor because of the high risk of bleeding and the possible unaesthetic aspect of the healed area (loss in the symmetry of the site). Only an expert in oral surgery can perform this kind of a surgery.

6.3 Lymphangiomas

Lymphangioma is a rare benign neoplasm that originates from the lymph vessels. Although rare, its treatment is difficult. This kind of a lesion appears and is detected within the first ten years of life, mostly on the dorsal and lateral border of the tongue. It rarely forms on the palate, cheek, or lips.

These can be conventionally treated by surgical excision, but in the case of an invasive lesion, CO₂ laser surgery has become preferred because of its ability to coagulate. Its main advantage is in vaporizing the lymph content and sealing the blood vessels during surgery. The aim of the surgery protocol is to generate a tissular overheating by the beam and produce a severe tissue necrosis that will be slowly replaced by fibrous tissue. The heat generated by the beam will induce the replacement of the lymphatic tissues by a new and more compact fibrous formation. By using this procedure, the lymphangioma will disappear and will be replaced by new and more desirable fibrous tissues.

Complete treatment of the pathology, as well as a long healing period are common results with this technical approach.

Definition	Benign neoplasm tumor. Originates from lymph vessels.
Macroscopic aspects	Soft with liquid content, containing some blood vesicles
Etiology	Developmental probable origin

Clinical Case:

A Caucasian female, 14 years old, had a lymphangioma on the right side of her tongue (Fig. 6.3.1 and Fig. 6.3.2). The clinical diagnosis was confirmed by technical examinations. The tumor appeared at an early age. A laser was used to deeply vaporize and coagulate the inner surface (Fig. 6.3.3), destroying all the tissues in the tumor by overheating and provoking the neo-regeneration of fibrous tissues. Small and limited tumors can be excised and vaporized. Great care must be taken during surgery in

order to avoid bleeding or any destruction of the noble structure involved or covered by the tumor. An excisional biopsy was done during surgery (Fig. 6.3.4). An adapted antibiotic, anti-inflammatory, analgesic, and a disinfecting mouth rinse solution were prescribed for the post-operative period. The healing process was very slow because of the importance of necrosis in overheated tissues. This process can take more than 4 weeks (Fig. 6.3.5 and Fig. 6.3.6). The long-term follow-up showed that the patient's recovery was stable (Fig. 6.3.7).



Fig 6.3.1: View of the lymphangioma on the right part of the tongue.

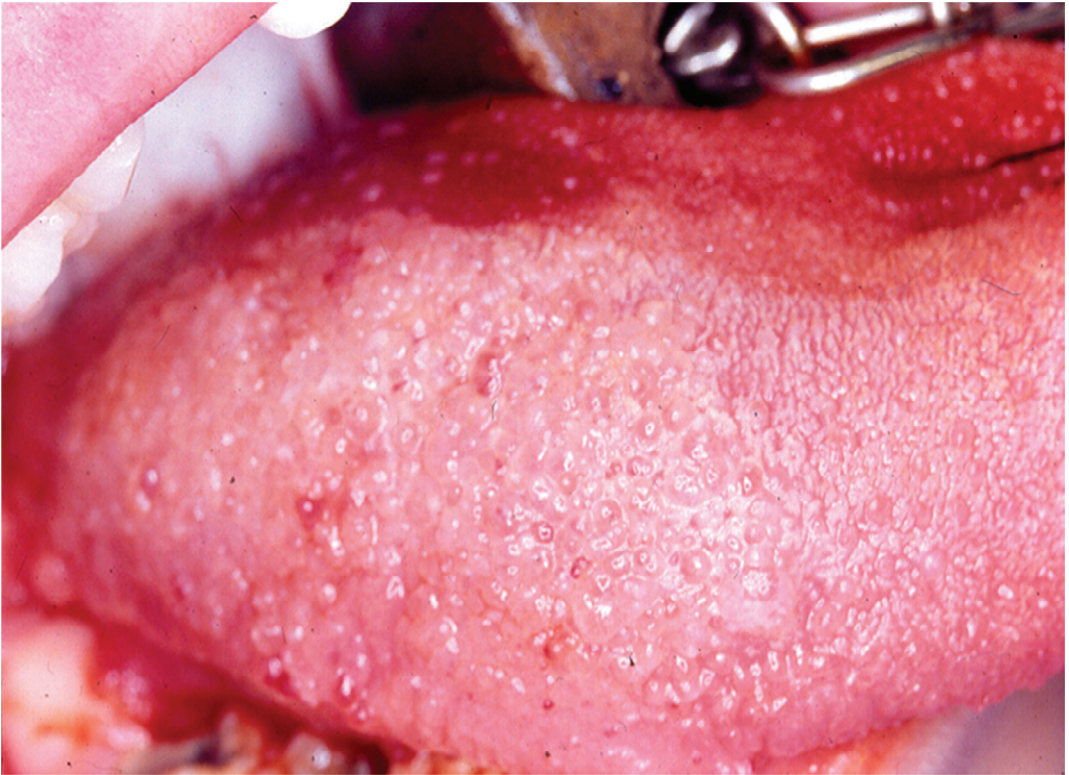


Fig 6.3.2: Lateral view of the lymphangioma on the right part of the tongue.

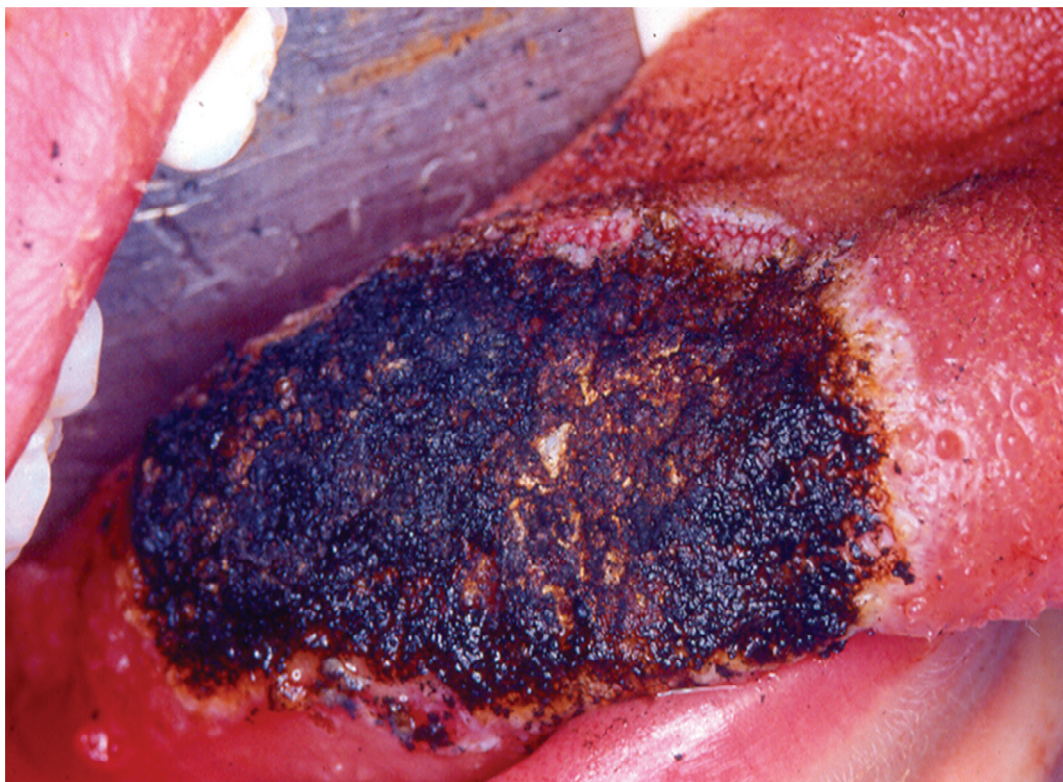


Fig 6.3.3: The surgery was conducted under general anesthesia. A laser beam was used in defocus mode to vaporize and to coagulate inner tissues of the tumor. At the end of the surgery, a soft pressure on the wound can detect any existing bleeding source in the cavity. In case of any appearance of bleeding, the laser beam will be used again in defocus mode to coagulate the opened blood vessel and to close it up. Small tumors can be removed by excision and vaporization. It is advised to keep the carbonization in the wound in order to decrease the risk of any future bleeding during the post-op period.

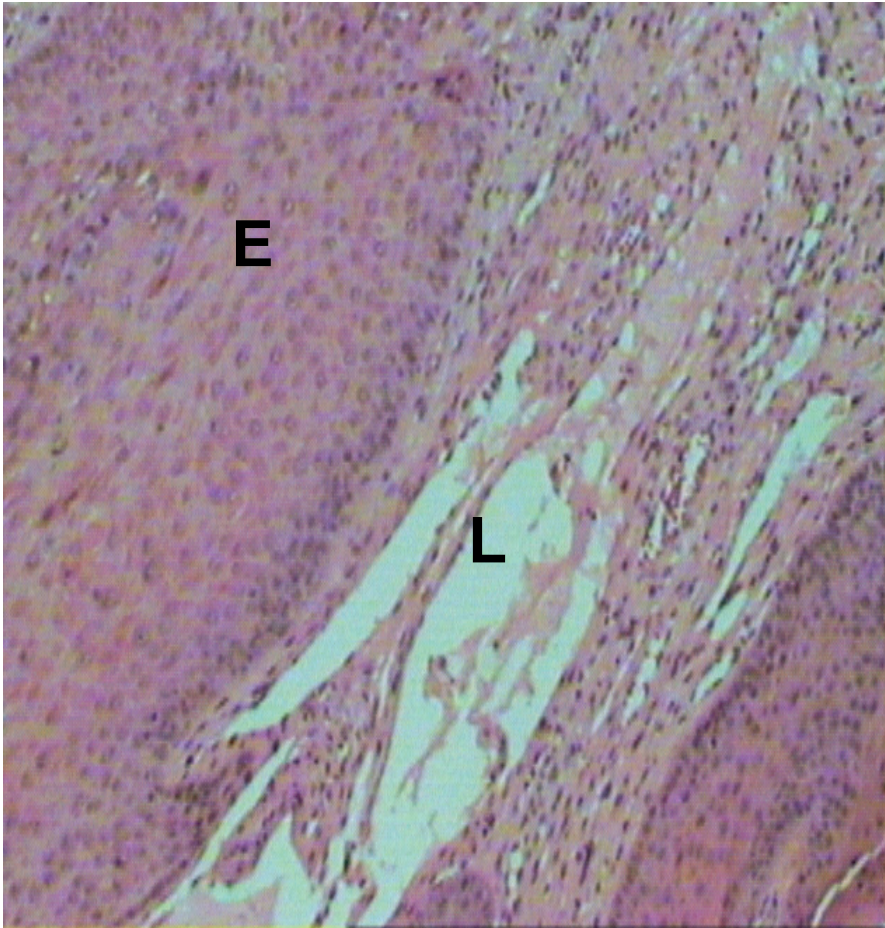


Fig. 6.3.4: Microscopic view of a Lymphangioma. L: Lymphatic distended tissue; E: Epithelium; original magnification: 40 X.



Fig. 6.3.5: View of the healed sites. The healing process is very slow because of the importance of necrosis in overheated tissues. It can take more than 4 weeks.



Fig. 6.3.6: View of the healed sites 2 months after surgery.

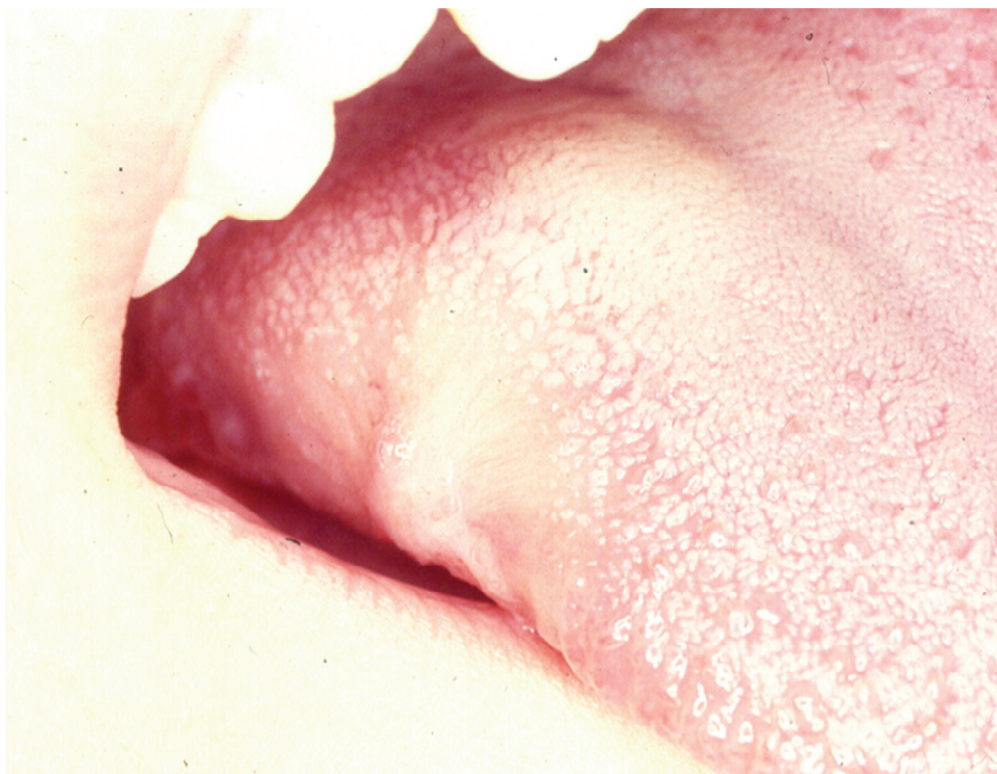


Fig. 6.3.7: View of the healed sites after one year of follow-up. The aspect of the tongue shows the persistence of the fibrous tissues in the operation site. No recurrence of the lymphangioma was noticed.

Laser irradiation conditions:

Mode	Continuous
Output power	2 Watts
Focus/defocus mode	Defocus mode for vaporization Focus mode for excision
Surgery	Excision if small tumor Vaporization by heat generated to dry the lymph and blood.

Great care should be taken during the ablation of this kind of a tumor because of the high risk of bleeding and the possible unaesthetic aspect of the healed area (i.e., loss in the symmetry of the site or anatomical deformation of the healed area). It is necessary to take care during surgeries to avoid damaging any noble structure (nerves, arterioles, etc.) involved with or existing under the tumor. This kind of surgery should be limited to a specialist in oral laser surgery because of the serious risk of hemorrhage.

PROSTHETIC SURGERY

Introduction

Adequate treatment planning is important for a successful outcome when prescribing removable partial and/or full dentures.

When requiring pre-prosthetic surgical procedures before the achievement of removable partial or full dentures, patients must be informed about the treatment plan.

The rational attitude in the pre-prosthetic surgery is to provide adequate oral habilitation and restoration to the patient using minimum surgical intervention.

Even if a large majority of edentulous patients manage to wear complete or partial dentures with relative ease, the making of complete dentures with enough retention and stability, using conventional means, has proved difficult for some.

According to the patients, the main complaints regarding prosthetic dentures are instability, loss in retention, and pain. Some patients are unable to chew normal food. In such clinical situations, the intra oral examination reveals, mainly but not solely, a marked atrophy of the alveolar ridge, prominence of sharp bony ridges, unfavorable frenulum insertion close to the crest, and insufficient vestibular depth. The treatment planning must include records of these unfavorable points. Further, the planning cannot ignore the fact that adaptation of the future dentures to these negative oral points is generally insufficient. Sometimes, there is a need for surgical procedures, such as frenectomy, vestibular deepening (vestibular extension procedures), smoothing or reducing sharp bony ridges (or, contrarily, augmentation procedures), or hyperplasia removal.

As the CO₂ laser has the ability to vaporize soft tissues without bleeding, the wound heals without scar formation and without any deformation of the healed site. Moreover, there is no need for sutures, which is the most important effect in the field of pre-prosthetic surgery, as any loss in vestibule lengths provoked by the suture is avoided. This wavelength is perfectly adapted for patients requiring soft tissue preparation management, as shown by the following clinical cases.

7.1 Denture-induced gingival or mucosal hyperplasia (Prosthetic Fibroma)

Etiologic factors of gingival hyperplasia are numerous: orthodontic treatment coupled with poor oral hygiene, drug-induced hyperplasia (phenytoine, nifedipine, cyclosporine, anticonvulsant, immunosuppressant, numerous calcium channel blocking agents), poor oral hygiene coupled with a hormonal disorder (puberty or pregnancy), a genet-

ic disorder, a symptom of a syndrome, etc. Local oral irritation may also induce a gingival or mucosal hyperplasia. A denture that is non-adapted or badly-adapted to a patient's oral structure can induce an important mucosal and fibrous hyperplasia (prosthetic fibromas).

When prosthetic fibromas are due to iatrogenic factors (the response of soft tissue to traumatic and chronic injuries), the dental practitioner has to identify and correct the etiologic factor in conjunction with the surgical removal of the hyperplastic tissue.

CO₂ laser surgery provides several benefits, including bloodless surgery, significant decrease of the operating time, and the elimination of the need for suturing. Eliminating suturing is an important advantage that allows for better retention of the denture because of the increase or preservation of the vestibular length after healing. The fibrins secreted by the lased wound will offer a better quality and better mechanical resistance to the gum or the mucosa.

Laser irradiation conditions:

Mode	Continuous or super-pulsed mode
Output power	6-15 watts
Focus/ defocus mode	Focus mode
Surgery	• Excision of the tumor • 1 mm of tissues layer thickness must be left on the bone surface during surgery. • No need for suturing (for healthy patients) • Removable existing denture must be immediately and temporarily relined with soft acrylic at the end of the surgery. • It is mandatory that the patient should wear his relined denture in mouth during 4 weeks after surgery.

Clinical case 1:

A Caucasian female, 72 years old, developed important maxillary prosthetic- induced fibromas because of a bad adaptation of the denture to the crest (Fig. 7.1.1). After

local anesthesia, the tumors were removed by excision with a focused beam of a CO₂ laser. There was no need to suture (Fig. 7.1.2 and Fig. 7.1.3).

The denture was relined temporary with a soft acrylic (Fig. 7.1.4) and kept in the mouth during the 4 weeks after surgery.

The healing showed a fibrous and healthy mucosa, which offered an excellent base for a new denture (Fig. 7.1.5).

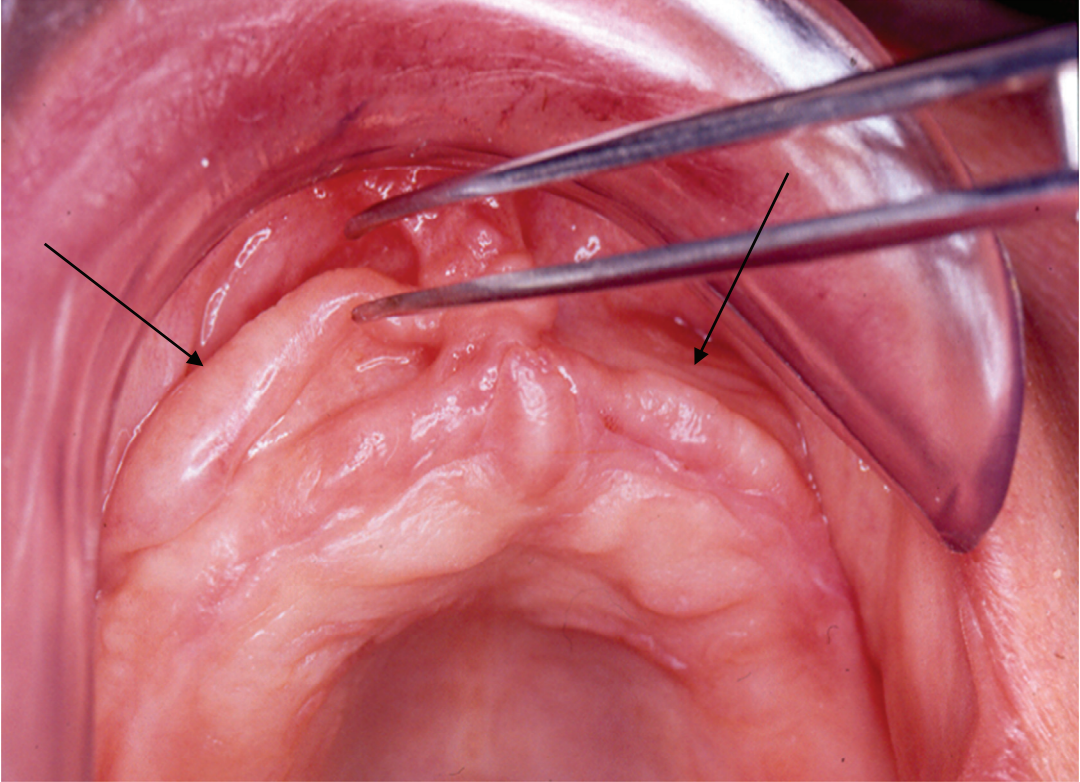


Fig 7.1.1: View of the important prosthodontic fibroma (double lip), which developed because of a bad adaptation of the denture. The patient wore her denture without any relining for a long time, inducing the sucking of the mucosa of the lip by continuous irritation. Arrows show the location of tumors forming the double lip.

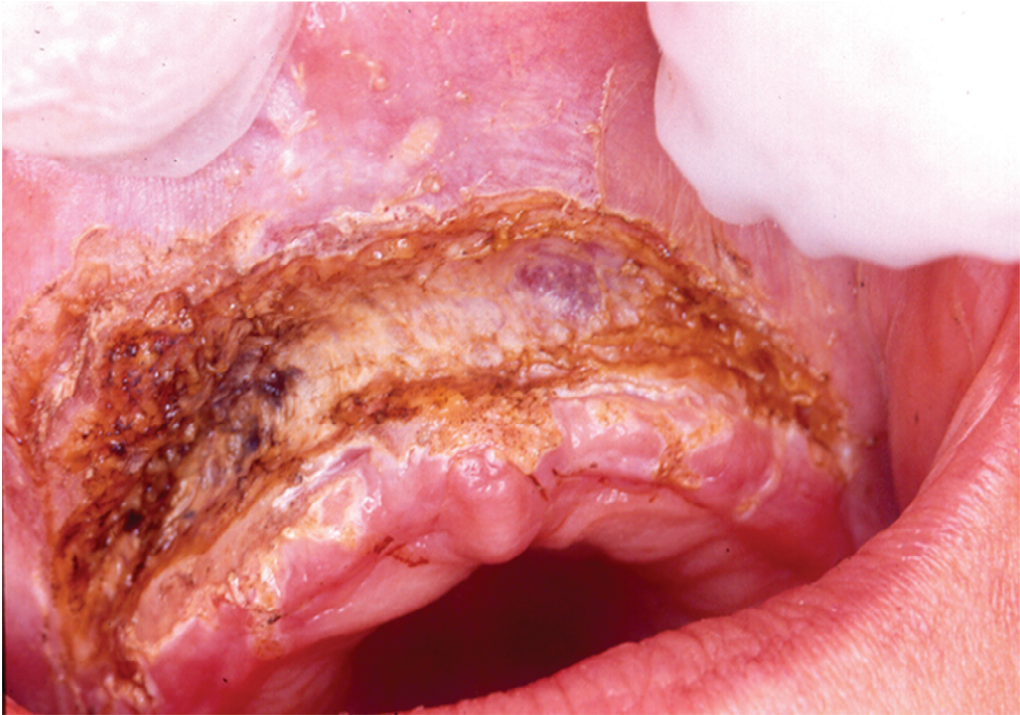


Fig. 7.1.2: Tumors were removed in one session under local and regional anesthesia. Hyperplastic tissues were removed by excision by means of a CO₂ laser in focus and continuous mode at 10 watts. The surgery was bloodless. There was no need to suture. During surgery, a slight vestibular lengthening was made in order to offer better stability to the future prosthetic denture.



Fig. 7.1.3: View of a part of the removed tumors.



Fig. 7.1.4: View of the temporary relined denture in the mouth.

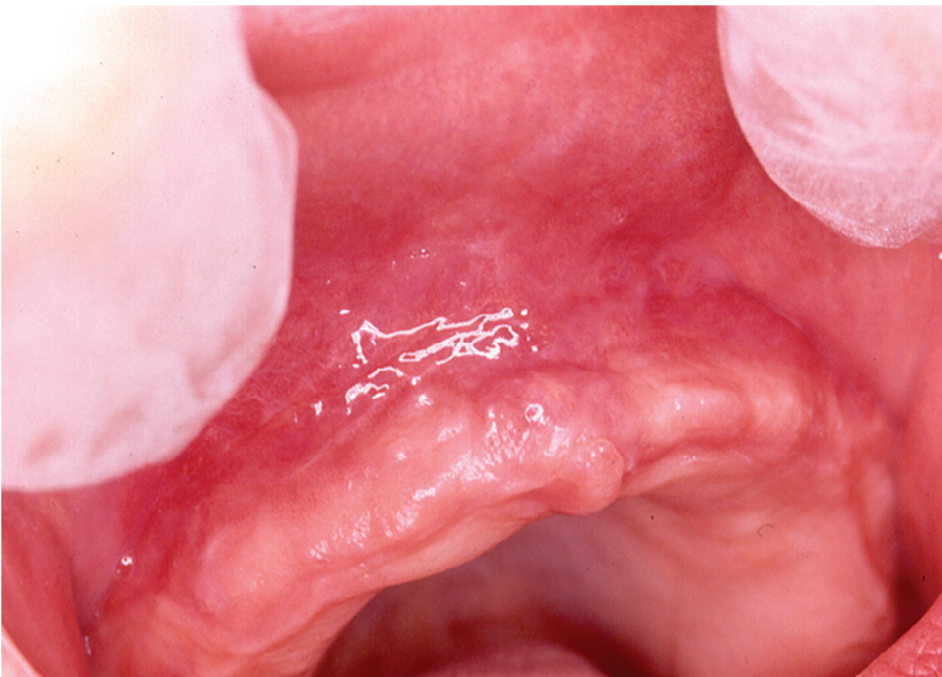


Fig. 7.1.5: View of the healed area, 4 weeks after surgery. The mucosa showed a healthy and fibrous aspect. The increase of vestibular deepening, done during surgery, was preserved. The new situation of the crest is more favorable to the future prosthetic structure.

Clinical case 2:

A Caucasian female, 83 years old, developed a mandibular prosthetic-induced fibroma in the anterior vestibule of the mandible because of a bad adaptation of her denture (Fig. 7.1.6). The tumor was removed by excision with a CO₂ laser in focus and continuous mode at 6 watts. No sutures were made (Fig. 7.1.7). It is recommended that the denture be immediately relined at the end of the surgery by a soft acrylic relining. The denture must be kept in the mouth of the patient during the 4 weeks of post-op. The immediate relining of the denture will allow conservation of the new and increased vestibule length. The healing was satisfactory (Fig. 7.1.8).

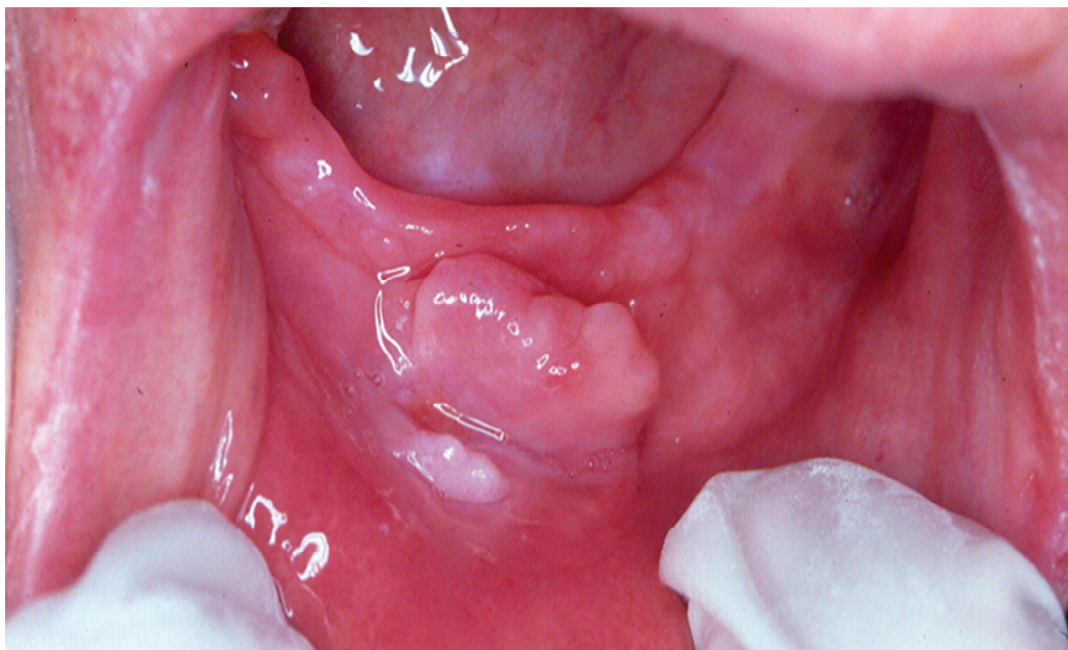


Fig 7.1.6: View of the mandibular prosthetic-induced fibroma that developed because of a bad adaptation of the denture. The patient had worn the denture without any relining for a long time. The unfavorable situation induced a sucking of the mucosa of the lip by continuous irritation.

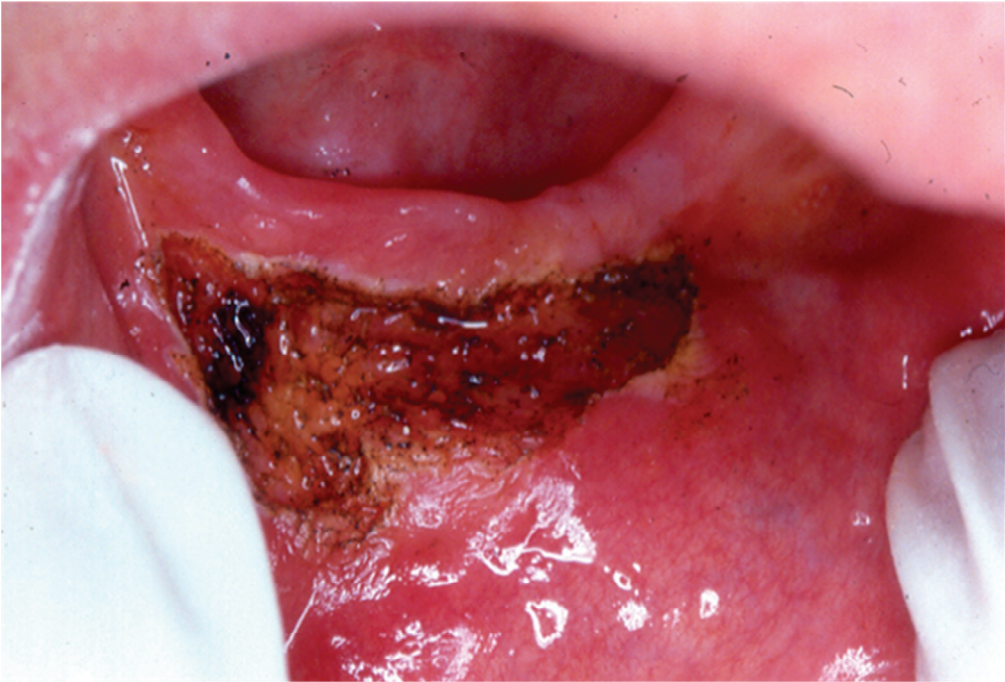


Fig. 7.1.7: The tumor was removed in one session under local and regional anesthesia. Hyperplastic tissues were removed by excision by means of a CO₂ laser in focus and continuous mode at 6 watts. The surgery was bloodless. There was no need to suture. The denture was not relined by a soft acrylic for the post-op period.

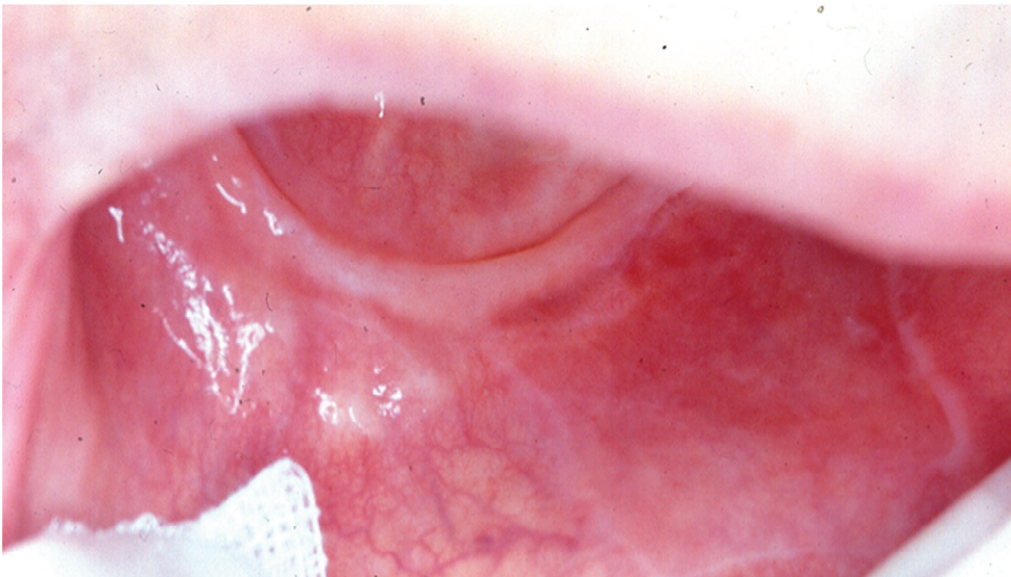


Fig. 7.1.8: View of the healing 4 weeks after surgery. The non-relining of the denture at the end of the surgery provoked the loss of the increased length of vestibule which was obtained during surgery). The vestibule healed at the same level that it had before surgery.

7.2 Vestibular deepening (increase of the crest length)

In case of advanced or severe resorption (atrophy) of alveolar processes and the body of the bone crest, vestibular lengthening should be helpful for the removable prosthetic structure. The main objective of this surgical approach is to enlarge the denture-bearing area and solve denture-related complaints. Vestibule-plasty is chosen when prosthetic stability is poor due to mandibular or maxillary crest atrophy and a small vestibule length.

If the situation of the bone structure of maxilla or mandible does not offer any possibility for vestibular deepening, surgery may be orientated to bone graft or to soft tissues autogenous grafts (palatal mucosa, full-thickness skin, dermal, reversed dermal, and meshed skin are used to provide sufficient vestibular depth). However, these techniques are reserved to specialist interventions, and have a high percentage of failure.

CO₂ technology provides a simple and secure method. The sutures and grafts are not needed.

Laser irradiation conditions:

Mode	Continuous
Output power	6 to 12 Watts
Focus/defocus mode	Focus mode
Surgery	• Excision, • 1 mm of tissues layer thickness must be left on the bone surface during surgery. No sutures. • Removable denture must be immediately and temporarily relined with soft acrylic • Patients should wear the denture for 3 to 4 weeks after surgery

Clinical case:

A Caucasian female, 81 years old, asked for a vestibular lengthening because of a severe problem with the stability of her denture (Fig. 7.2.1). She could not afford the

implant systems which can be the best choice for this kind of a situation of oral habilitation.

After local anaesthesia, the surgery was completed by means of a CO₂ laser in continuous mode at 12 watts. A thin layer of approximately ± 1 mm was left on the surface of the maxillary bone. A large and total vestibular lengthening was done (Fig. 7.2.2) with as much consideration as possible to maxillary structures (the excision was stopped at 2 mm from the end of the bone structure).

The denture of the patient was immediately relined with a soft acrylic (Fig. 7.2.3) and worn at all times by the patient during the 6 weeks before starting to wear a new denture. The healed mucosa seemed healthy, fibrous, and attached to the bone (Fig. 7.2.4 and Fig. 7.2.5).

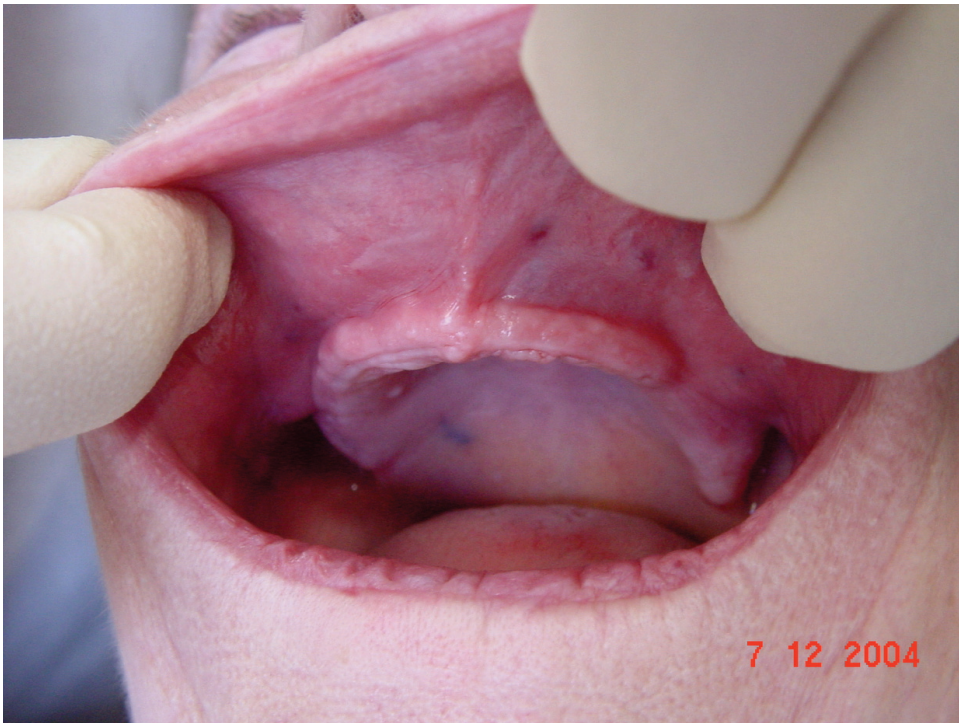


Fig 7.2.1: The maxillary crest had a severe resorption. The height of the crest did not offer enough stability to the denture.



Fig 7.2.2: View of the vestibular lengthening at the end of the surgery. There was no need for sutures. The wound was bloodless. After the patient was given local anaesthesia, the surgery was performed with a CO₂ laser in continuous mode at 12 watts. A thin layer of approximately ± 1 mm was left on the surface of the maxillary bone. A large and total vestibular lengthening was done with as much consideration as possible to maxillary structures (the excision was stopped at 2 mm from the end of the bone structure).

The denture of the patient was immediately relined by a soft acrylic. It was recommended that the patient keep the denture in her mouth at all times during the healing period.



Fig 7.2.3: View of the denture that was relined immediately after surgery. The patient kept the denture in her mouth during the 6 weeks following the surgery. The patient removed the denture only for hygienic purposes.

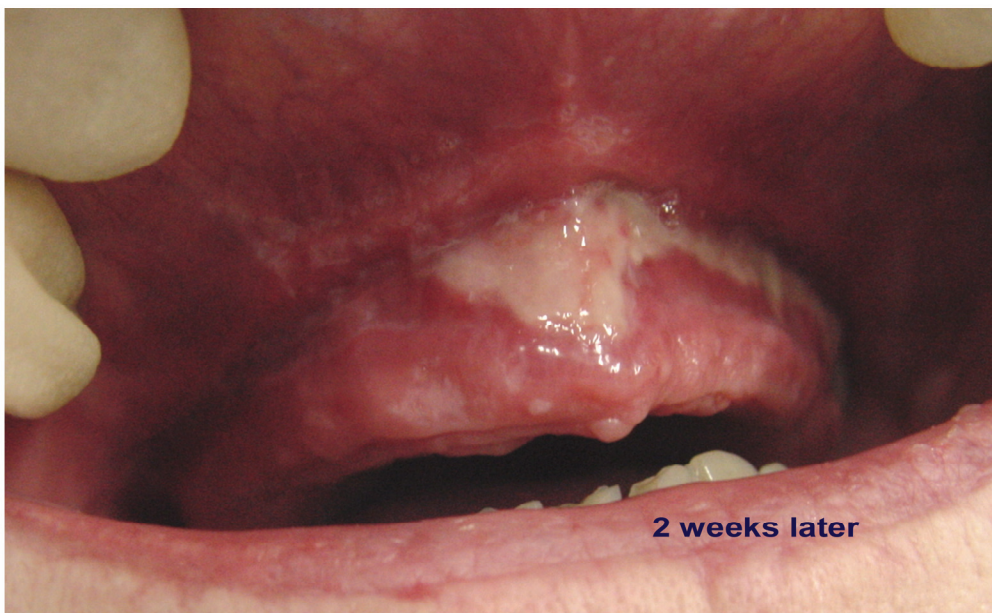


Fig 7.2.4: View of the vestibular lengthening after 2 weeks. The healing was not yet complete. Fibrins are still covering the wound.



Fig 7.2.5: View of the vestibular lengthening after 6 weeks. The healing was complete. The crest now offers better retention for any future prosthetic denture.

7.3 Frenectomy

The presence of labial frenulum (median or laterals) may cause instability of the oral prosthetic structure. The movements of the lips (traction test) may cause a loss in denture retention and/or a mobility of the future prosthetic denture.

In a total or partial edentulous patient, a frenulum that is part-attached on the maxilla or mandible crest should be removed to increase the retention of the denture.

Laser irradiation conditions:

Mode	Continuous or super-pulsed
Output power	6 to 12 Watts
Focus/defocus mode	Focus mode
Surgery	Incision 1 mm of tissues layer thickness must be left on the bone surface during surgery. No sutures. Removable denture must be immediately and temporary rebased with soft acrylic Patients should wear the denture for 3 to 4 weeks after surgery

Clinical case:

A Caucasian male, 52 years old, asked for an oral rehabilitation by removable prosthetic denture. Before starting the treatment, it was necessary to prepare the maxillary crest for the rehabilitation. It was decided to perform some labial frenectomies (median and laterals) (fig. 7.3.1).

After giving local anaesthesia at the sites of the surgeries, a CO₂ laser was used in focus, continuous and non contact mode at 6 Watts. A laser beam was used to vaporize the frenulum. A thin layer of a minimum of 1 mm of soft tissues should be kept to cover the maxillary bone until the end of the vestibule (fig. 7.3.2). The insertion of the frenulum at the level of the lip should also be removed. The Lotagene solution was used to remove the carbonized layer covering the surgery site. Sutures were made only on the lip's side of the frenulum (Fig.7.3.3).

The patient should use a topical application after each meal in order to avoid a secondary infection of the wound. An analgesic can be prescribed for one or two days. For healthy patients, it is not necessary to prescribe an antibiotic. The healing aspect of the wound was satisfactory (fig. 7.3.4).



Figure 7.3.1: View of the median and lateral frenulum.



Figure 7.3.2: View of the surgery sites. A thin layer of ± 1 mm of soft tissues was left covering the maxillary bone. The carbonization is clearly visible at the border of the flaps. The carbonization should be removed.



Figure 7.3.3: The lip's side of the wound was sutured to avoid the rebound of the frenulum re-insertion at the maxilla side.



Figure 7.3.4: View of the healing. The results are satisfactory.

7.4 Crown lengthening

Crown lengthening procedures are used to restore fractured teeth caused by important caries or traumas. In some clinical cases, forced tooth extrusion (orthodontic treatment) or surgical apical re-positioning of the labial side of the gum may be used as an alternative to gingivectomy.

In the aesthetic zones, crown lengthening may be considered after any careful restorative treatment planning.

In some cases, in order to accomplish an adequate and important crown lengthening, the practitioner will be obliged to make an osseous ablation.

Laser irradiation conditions:

Mode	Continuous or super-pulsed
Output power	2 to 6 Watts
Focus/ defocus mode	Focus mode
Surgery	Excision, followed by a gingival re-contouring

Clinical case:

A 78-year-old Caucasian female had totally fractured her teeth in an accident (7.4.1). She asked to preserve her fractured teeth in order to use them for an eventual prosthetic re-habilitation. A local anaesthesia was given. A CO₂ laser was used at focus, continuous and non contact mode at 4 Watts. A total gingivectomy of the fractured teeth was done, coupled with a gingival re-contouring (figure 7.4.2). The exposure of the teeth surfaces allowed root canal treatments. After 6 days, the crown lengthening was stable without any rebound in the gum level or supplementary gum receding (figure 7.4.3). The gum seemed completely recovered.



Figure 7.4.1: View of the deep fractures of the teeth. The position of the gum does not allow for any appropriate treatment of the fractured teeth.



Figure 7.4.2: View of the teeth at the end of the gingival re-contouring. The exposure of the root surfaces makes future dental treatment possible.



Figure 7.4.3: View of the gingival healing after 6 days. The exposure of the roots allowed for easy treatment of the fractured teeth. The gum seemed completely recovered.

7.5 Floppy ridges

Even if benign, a floppy ridge, which is a replacement of the alveolar bone by fibrous tissue, may present a considerable challenge to the dental practitioner when providing a complete denture.

Some conventional surgical techniques combine vestibular deepening and excision of the floppy ridge, plus ridge augmentation with hydroxyapatite.

The use of the CO₂ laser in this kind of a surgery can allow for the following:

- Excision of the floppy ridge
- Vestibular deepening, if judged necessary to increase the ridge length.

Laser irradiation conditions:

Mode	Continuous or super-pulsed
Output power	4 to 12 Watts
Focus/ defocus mode	Focus mode
Surgery	• Excision • Vaporization in case of small volume to ablate. • A tissues layer of ± 1 mm thickness must be left on the bone surface of surgical site. • No sutures. • Removable denture must be immediately and temporary re-lined with soft acrylic • Patients should wear the denture for 3 to 4 weeks after surgery

Clinical case:

A 77-year-old Caucasian female asked for the ablation of the multiple floppy ridges on her maxillary crest (figure 7.5.1). After giving a local anaesthesia, a CO₂ laser was used at focus, continuous and non contact mode at 4 watts. A total excision of the floppy and fibrous areas of the crest was made, coupled with a gingival remodelling (figure 7.5.2 and figure 7.5.3). The denture was immediately relined by a soft acrylic. The patient kept the denture in her mouth for 4 weeks before starting any treatment for a new denture. After 2 weeks, the wound seemed completely recovered (figure 7.5.4). No recurrence was noted. The healed mucosa had a fibrous consistency and healthy aspect.

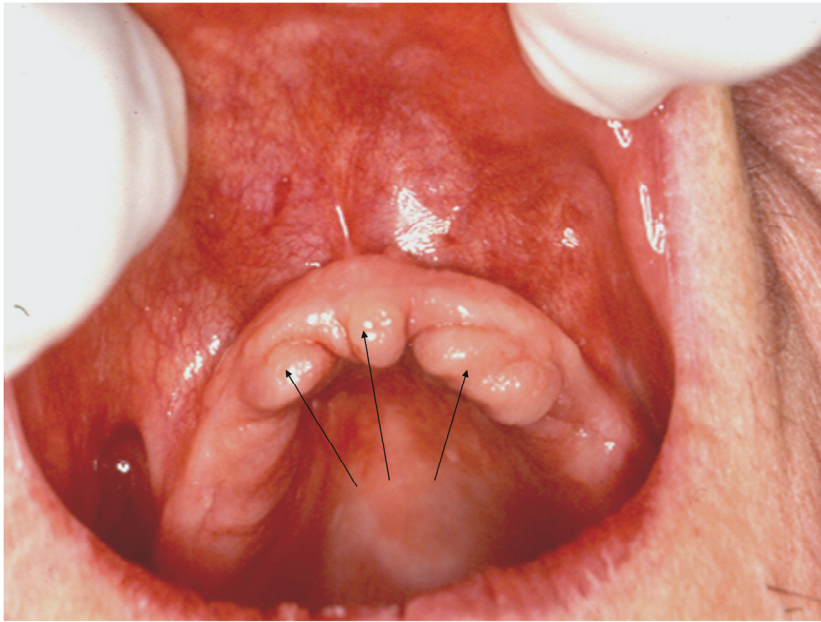


Figure 7.5.1: View of the floppy maxillary ridge. The arrows are indicating the position of the floppy and fibrous areas of the crest.

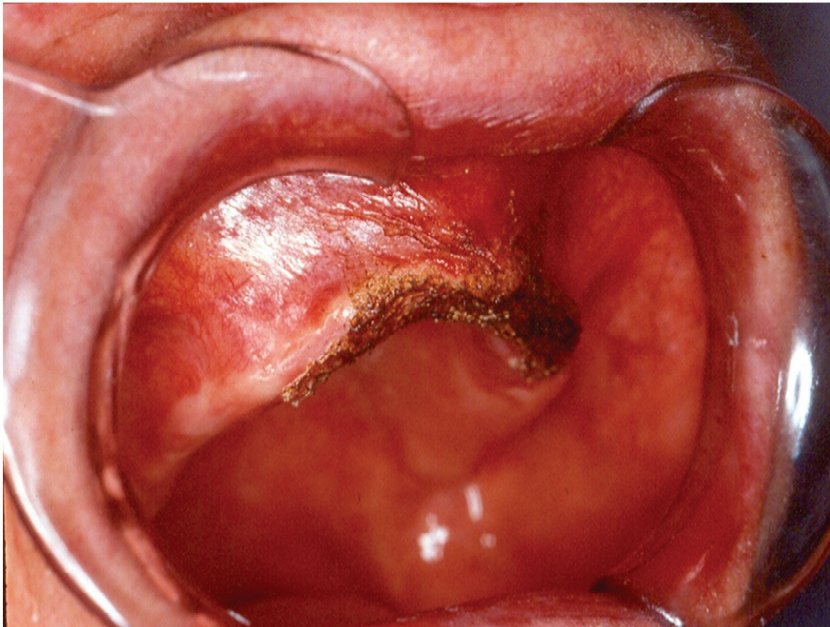


Figure 7.5.2: View of the excised floppy and fibrous areas of the maxillary ridge. The carbonized tissues were removed to allow a quick healing of the wounded areas.



Figure 7.5.3: Similar view to figure 7.5.2 of the excised floppy and fibrous areas of the maxillary ridge.



Figure 7.5.4: View of the healing of excised floppy and fibrous areas of the maxillary ridge. The healing was satisfactory.

ORTHODONTIC SURGERY

A multidisciplinary approach seems to be necessary to treat some problems concerning orthodontics. Sometimes, oral surgeries are necessary for the success of orthodontic treatments. The Co₂ laser has some clinical indications in orthodontic surgery:

- Frenectomy (lingual and Labial)
- Impacted teeth
- Gingivoplasty
- Crown lengthening

The periodontal conditions have to be taken into account during or at the end of orthodontic or surgical treatments.

8.1 Frenectomy (lingual and labial)

8.1 A: Tongue frenulum ablation

The consequences of not treating an improper tongue-tie could be long-reaching, as this organ can influence the mandible, and thus, facial development.

The tongue-tie keeps the tongue in a low position at the level of the mandible producing an exclusive induction of the mandible's development and not enough excitation for upper maxillary growth. This pathology of the low position of the tongue may induce abnormal or alteration in the face development.

Frenectomy is indicated by the presence of altered lingual functions caused by the tongue-tie, such as speech or deglutition problems and lingual dysfunction.

Laser irradiation conditions:

Mode	Continuous or super-pulsed mode
Output power	4- 6 watts
Focus/ defocus mode	Focus mode except for haemostatic purpose.
Surgery	Incision and ablation of the frenulum insertion Suture exclusively at the site of the insertion of the frenulum in the tongue

Clinical case:

An 8-year-old Caucasian child had a bad insertion of the tongue and a tongue-tie problem (figure 8.1.1 and figure 8.1.2). After giving a local anesthesia, a CO₂ laser was used at focus, continuous and non-contact mode at 4 watts. A total excision of the frenulum was made coupled with a tissue remodelling of the edges of the wound (figure 8.1.3). The carbonized tissues were removed. A suture was made for a limited area: at the tongue-side insertion of the frenulum. The rest of the wound was left without any suture (figure 8.1.4). The aim of the suture was to avoid any eventual rebound in the frenulum insertion. The wound seemed completely recovered after 2 weeks (figure 8.1.5). No recurrence was noted after 1 year.



Figure 8.1.1: View of the tongue. The patient had difficulty sticking out his tongue. Notice the “V” shape at the tip of the tongue.



Figure 8.1.2: View of tongue-tie. The lingual frenulum kept the tongue in a low position.

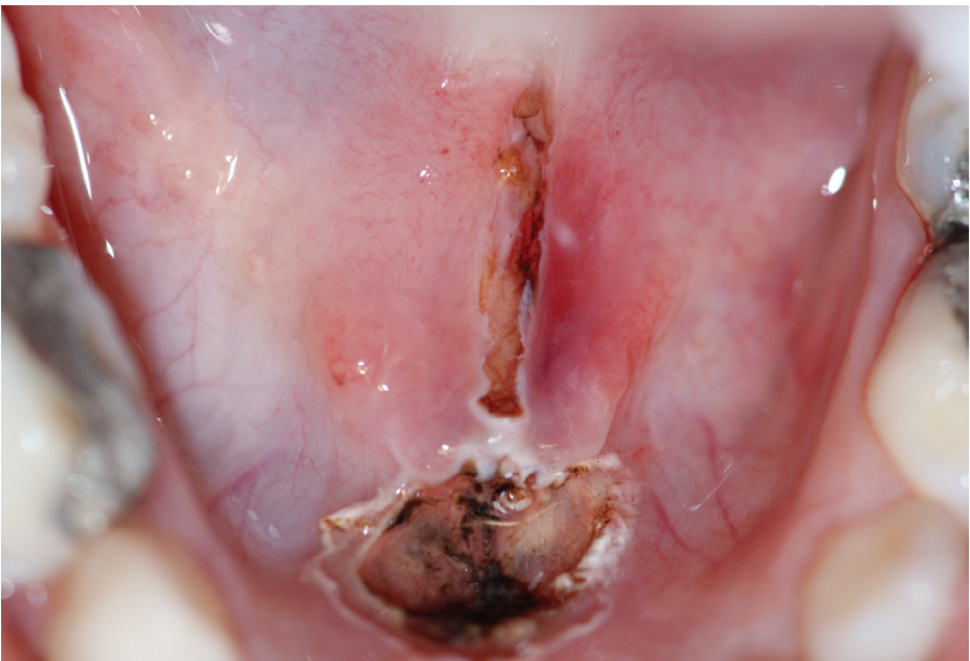


Figure 8.1.3: View of the surgical site. The area that includes the salivary canals was left out from the laser beam action.



Figure 8.1.4: A suture was made for a limited area: the tongue-side insertion of the frenulum. The rest of the wound was left without any suture. The aim of the suture is to avoid any eventual rebound in the frenulum insertion.



Figure 8.1.5: The wound seemed completely recovered after 2 weeks. The frenulum was entirely removed allowing mobility of the tongue.

8.1. B: Labial frenulum

The relationship between a clinically “abnormal” maxillary median frenulum and a median diastema shows a strong, but not absolute, correlation. The problem for the clinician is differentiating between “cause” and “effect.” In fact, all observations are based on the stronger potential of relapse after orthodontic diastema closure because of the presence of a median labial frenulum with important fibrous insertion between the central incisors.

The decision to surgically ablate the frenulum is recommended only when complete eruption of the permanent teeth is observed, with a consensus not being clear on those teeth (lateral incisors or canines). Frenectomy should be done after the canines have erupted (never during deciduous dentition).

The labial frenulum seems to play a role in the induction of the maxillaries’ development. A frenectomy will stop the part of frenulum excitation of development and growth of maxillaries. Before the decision to conduct a frenectomy is made, severe analysis of the frenectomy indication must be done to avoid an alteration in the maxillaries’ growth.

In case of the existence of a diastema between the central incisors and prior to any orthodontic treatment, a surgical ablation by means of a CO₂ laser helps ensure a good prognosis. CO₂ laser surgery offers several advantages: complete removal of fibrous tissues in the papilla, removal of the fibers strongly linked in the palatal intermaxillaries suture between incisors, bloodless surgery, no need for suturing after surgery, and good quality, healed tissues.

Laser irradiation conditions:

Mode	Continuous or super-pulsed mode
Output power	4- 6 watts
Focus/ defocus mode	Focus mode except for haemostatic purpose
Surgery	Incision and ablation of the frenulum insertion

Clinical case:

A labial maxillary frenulo-plasty was to be performed in the mouth of a 9-year-old Caucasian male prior to an orthodontic treatment of the inter-central incisors diastema (figure 8.1.6). Local anesthesia was given. A CO₂ laser was used at focus, continuous and in non-contact mode at 4 watts. A total excision of the frenulum was made, coupled with vaporization and an ablation of the fibrous insertion of the frenulum at the palatal inter-maxillaries suture (figure 8.1.7 and figure 8.1.8). The carbonized tissues were removed. A suture was made for a limited area: at the lip's insertion of the frenulum. The rest of the wound was left without any sutures. The aim of the suture was to avoid any eventual rebound in the frenulum insertion. The wound seemed completely recovered after 2 weeks (figure 8.1.9). No recurrence was noted after 1 year.



Figure 8.1.6: View of the inter-central incisors diastema on the maxilla.



Figure 8.1.7: Labial view of the frenectomy. A limited ablation of the frenulum was made. The palatal insertion of the frenulum at the inter-maxillaries suture was removed and vaporized.



Figure 8.1.8: Palatal view of the frenectomy. The palatal insertion of the frenulum at the inter-maxillaries suture was removed and vaporized. The bone exposition can be seen at the palatal inter-maxillaries suture. In the palate, the surgery border was stopped before the nasal-palatal orifice in order to preserve the nerve and vascular system of that area.



Figure 8.1.9: View of the healed area. The natural movement of the incisors closing the diastema can be noticed clearly (see arrow).

8.2 Impacted tooth exposure and bracket placement

IMPACTED TEETH

Teeth retained by impaction might cause problems (loss of teeth in the occlusion), and complications might occur resulting from abnormal development.

Impaction occurs more frequently with maxillary canines than with any other tooth, with the exception of the maxillary or mandible third molars. The main objective of the treatment is to facilitate the recreation of the anatomical structures in the canine region. It is based on surgical and orthodontic traction of the impacted canine. Once the surgical crown exposition is complete, brackets are placed, and ligature for orthodontic extrusion is done, the mechanical strategy leads to the desired aesthetic, and functional and occlusal treatment goals.

The surgical phase is decisive for correct tooth repositioning in order to facilitate the procedure and minimal subsequent orthodontic work, while ensuring maximum stability of both the tooth and the periodontal tissue at the end of the repositioning.

An apically repositioned flap and suturing of the flap may be performed conventionally for the exposition of the impacted tooth. The advantage of using the CO₂ laser is the way it exposes the impacted tooth by tissue vaporization. The surgery field is bloodless, which allows immediate bonding of an orthodontic traction hook (with a ligature chain) to the exposed enamel of the impacted tooth. These procedures are accomplished at one time. A periodontal dressing may be placed over the surgical area for a period of time.

If conventional surgery is used, some pre-operative and post-operative problems may occur when placing the brackets. These problems are caused by enamel that is wet due to bleeding: it does not meet the required conditions for bracket bonding immediately after surgery.

In a conventional procedure, some complications may occur:

- Premature relapse in post-op period of the impaction at the time of pack removal for bracket bonding,
- Sutures breakdown in post-op period before the bonding of brackets (if the decision is made to wait a minimum of 24 hours before bonding the brackets).

All of these complications may be avoided if the CO₂ laser beam is used. An absence of bleeding considered necessary for the efficacy of the enamel acid etching, as well as immediate bonding of the light cured composite resin characterize this method.

Laser irradiation conditions:

Mode	Continuous or super-pulsed mode
Output power	4 – 6 watts
Focus/defocus mode	Focus mode for the vaporization and the excision of tissues covering the impacted tooth. The tooth surface must be protected during laser irradiation by insertion of an adapted tool between the enamel and the tissue that is to be excised. Defocus mode in case of any bleeding.
Surgery	Vaporization and excision of tissues covering the impacted tooth.

Clinical case:

A 10-year-old Caucasian male had an impacted tooth (lower left canine) in a bad position for spontaneous eruption. A conventional surgery was performed 4 weeks earlier without success because the sutures broke down in the post-op period before the bonding of the brackets (figure 8.2.1).

We decided to expose the enamel surface of the impacted canine in order to bond, in the same session, an orthodontic system for tooth traction. A local anesthesia was given prior to the surgery. A CO₂ laser was used at focus, continuous and non-contact mode at 4 watts. First, a superficial vaporization of tissues covering the tooth was done to allow insertion of an adapted tool between these tissues and the enamel surface of the impacted tooth. After protection of the impacted canine surface, an excision of the tissue of impaction was done allowing a large and total exposure of the enamel surface (figure 8.2.2). The surgery field was bloodless, allowing immediate bonding of the orthodontic traction system in the same session (figure 8.2.3).

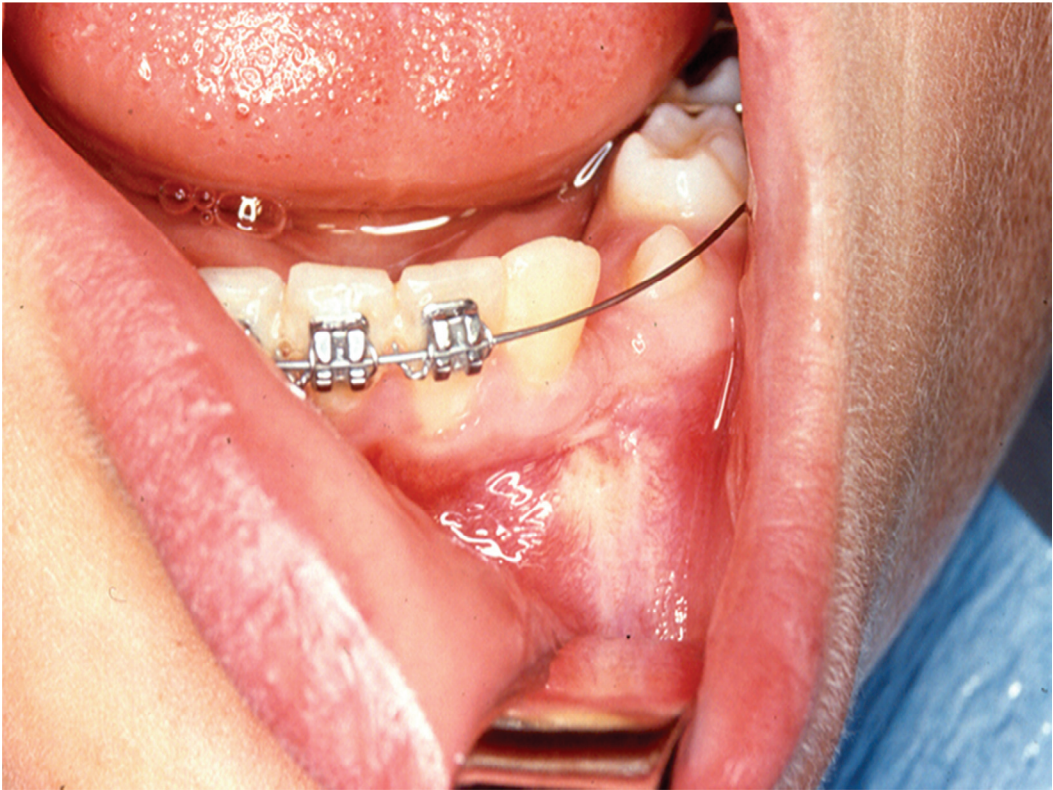


Figure 8.2.1: View of the area of the impacted canine. An unsuccessful conventional surgery was performed 4 weeks earlier.

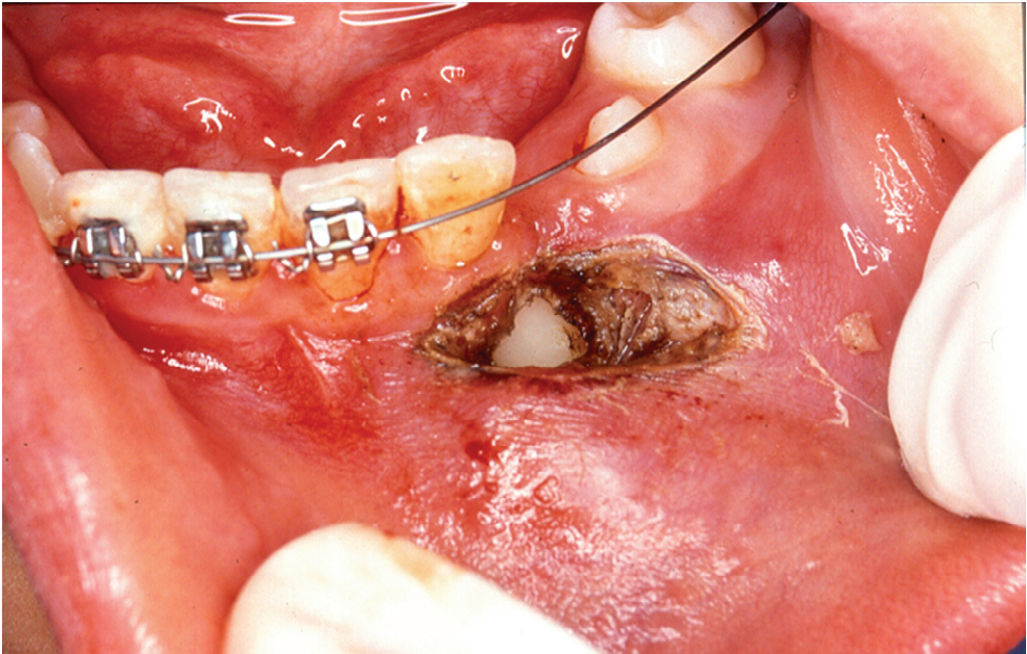


Figure 8.2.2: The enamel surface of the impacted canine was exposed for an immediate bonding to an orthodontic traction system in the same session. Note the bloodless operative field.



Figure 8.2.3: The orthodontic traction system was immediately bonded to the exposed surface of the impacted canine. The surgery and the bonding of the orthodontic traction system were done in the same session.

8.3 Gingival hyperplasia

As described in the preceding chapters, there are many reasons that patients develop gingival hyperplasia. These reasons include orthodontic treatment coupled with poor oral hygiene, drug-induced hyperplasia, poor oral hygiene coupled with a hormonal disorder (puberty or pregnancy), a genetic disorder, or the symptom of a syndrome.

To facilitate bracket positioning, gingivectomy of the hyperplastic gum may represent the first step of the orthodontic treatment. A gingivectomy may also be performed in the area to facilitate teeth brushing and reduce the risk of recurrence. Orthodontic treatment coupled with poor oral hygiene may provoke the appearance of a hyperplastic gum. During the orthodontic treatment, CO₂ laser surgery may be engaged to treat a gingival hyperplasia. Prophylaxis takes an essential part of the treatment protocol. On the other hand, orthodontic devices may produce plaque retention or exacerbate the gingival inflammation inducing a hyperplastic soft tissue development. The main objective of the CO₂ laser treatment is to stop the periodontal irritation that may progress sub-clinically.

Laser irradiation conditions:

Mode	Continuous or super-pulsed mode
Output power	4 – 9 watts
Focus/defocus mode	Focus mode for the vaporization and the excision of hyperplastic tissues. The tooth surface must be protected during the laser surgery by insertion of an adapted tool between the enamel and the tissue.
Surgery	Vaporization and excision of hyperplastic tissues

Clinical case:

A 16-year-old Caucasian female had a gingival hyperplasia during her orthodontic treatment (figure 8.3.1).

It was decided to perform a gingivectomy. A local anesthesia was given prior to the surgery. A CO₂ laser was used at focus, continuous and non-contact mode at 4 watts. First, an adapted tool was inserted between the hyperplastic tissues and the enamel surfaces of the teeth. Next, an excision of the hyperplastic tissue was done followed by a gingival re-contouring for each tooth. (8.3.2). The gum healing was satisfactory after 8 days (figure 8.3.3).



Figure 8.3.1: View of the gingival hyperplasia on lower teeth during an orthodontic treatment.



Figure 8.3.2: View of the gingival hyperplasia removal at the end of the surgery. A gingival re-contouring was made for each tooth.



Figure 8.3.3: The gum healing was satisfactory after 9 days.

8.4 Crown lengthening

To facilitate bracket positioning and bonding, crown lengthening is sometimes the first step of orthodontic treatment. In order to expose the enamel surface (covered by the gum), a gingivectomy may be performed. The gingivectomy should be coupled with a gingival re-contouring of the concerned tooth. This treatment should be performed prior to the orthodontic treatment. The advantages of the use of the CO₂ laser in this kind of surgery are:

- Stability of the results of the gingivectomy. No gingival receding was noticed in the post-op period. The level of gingival cutting at the moment of the surgery stayed stable during and after the healing period without any supplementary gingival receding. This stability in the results is due to the high absorption of CO₂ laser beam by oral soft tissues and the superficial heat generation in the lased tissues.
- Absence or dramatic decrease of pain in the post-operative period.
- The appreciated quality of the fibrous healed gum (rich in fibrins secreted by lased tissues after surgery).

Laser irradiation conditions:

Mode	Continuous or super-pulsed mode
Output power	4 – 6 watts
Focus/defocus mode	Focus mode for the vaporization and the excision of hyperplastic tissues. The tooth surface must be protected during laser by insertion of an adapted tool between the enamel and the tissue.
Surgery	Vaporization and excision of hyperplastic tissues.

Clinical case:

A 12-year-old Caucasian female needed crown lengthening on her upper canines. The enamel of the crowns was covered by the gum. This situation did not allow for adequate orthodontic treatment because it was impossible to bond any orthodontic brackets to these teeth (figure 8.4.1).

It was decided to make a gingivectomy on the concerned teeth. A local anesthesia was given prior to the surgery. A CO₂ laser was used at focus, continuous and non-contact mode at 4 watts. First, an adapted tool was inserted between the tooth gum and the enamel surface. Next, an excision of the gum was done followed by a gingival re-contouring for each tooth. (8.4.2). The gum healing was satisfactory after 8 days (figure 8.4.3).



Figure 8.4.1: The gum covering the labial crown surface did not allow for bonding of any orthodontic bracket.



Figure 8.4.2: View of the teeth at the end of the surgery



Figure 8.4.3: View of the healed gum of the upper canines. No more gingival receding was noticed in the post-operative period. The cervical gum level stayed stable.

PERIODONTAL SURGERY

In the field of periodontology, research is progressing continuously, revealing many indications for clinical applications of laser surgery.

Three main indications have become evident, although further research is necessary. The use of the CO₂ laser beam has some advantages in periodontal surgery:

- The decontamination effect of the laser beam is important for the treatment of gingivitis and peri-implantitis. Prior to any clinical use, the dental practitioner should be informed about the thermal side effects of laser beams.
- The haemostatic properties of laser beams can be perfectly adapted for periodontal surgeries.
- Gingival re-contouring can be done and re-designed easily in a good clinical condition.

In periodontal surgery, the use of CO₂ laser is mainly limited to the periodontal soft tissues. The dental hard tissues (enamel, dentin, cement) cannot be exposed to this kind of a laser beam because of the possibility of thermal damage. Therefore, for the treatment of bony defects, the CO₂ laser beam can be used during the surgical procedure for the following reasons: its decontamination potential, the vaporization and the curettage of the granulation tissue, the removal of the superficial layer of the infected bony pocket (in super-pulse mode) in which the bone resorption process is engaged in the aim to provoke an inversion of the resorption to a bone regeneration process, and finally, for the 4 mm of de-epithelisation of the gum.

9.1 Gingivectomy

As described previously, there are many reasons that a patient may develop gingival hyperplasia: bad oral hygiene and the existence of plaque, biofilm and tarter in the gingival pocket, orthodontic treatment coupled with poor oral hygiene, drug-induced hyperplasia, poor oral hygiene coupled with a hormonal disorder (puberty or pregnancy), a genetic disorder, or as a symptom of a syndrome.

For the treatment of the gingival pocket, gingivectomy of the hyperplasic gum may be considered if non-surgical procedures fail to treat the problem. The gingivectomy should be concurrent with the removal of irritant agents (tarter, biofilm, etc.)

from the gingival pocket and patient education regarding adapted oral hygiene. Good oral hygiene will reduce the risk of recurrence.

The main objective of the CO₂ laser treatment is to decontaminate the gum, and to cut and make a gingival re-contouring. The surgery is bloodless. The CO₂ laser beam has a haemostatic and regenerative effect. Six hours after a laser surgery, the laser beam provokes a collagen secretion in lased soft tissues. The healed gum becomes richer in collagen.

Laser irradiation conditions:

Mode	Continuous or super-pulsed mode
Output power	4 – 6 watts
Focus/defocus mode	Focus mode for the vaporization and the excision of hyperplasic tissues. The tooth surface must be protected during laser by insertion of an adapted tool between the enamel and the tissue.
Surgery	Vaporization and excision of hyperplasic tissues.

Clinical case:

A 46-year-old Caucasian female asked for a gingivectomy because of the unaesthetic nature of her smile. The crowns of her teeth were covered by a hyperplasic gum (figure 9.1.1). The patient was given medicine for her epilepsy.

We decided to perform a gingivectomy on the concerned teeth. A local anesthesia was given prior to the surgery. A CO₂ laser was used at focus, continuous and non-contact mode at 6 watts. First, an adapted metallic tool was inserted between the tooth gum and the enamel surface. Next, an excision of the gum was made, followed by a gingival re-contouring for each tooth. (9.1.2). The gum healing was satisfactory after 8 days (figure 9.1.3 and figure 9.1.4). A recurrence of the gingival hyperplasia can occur in the first year following surgery if the patient is not consistent in taking his or her medicine. The treatment of gingivectomy can be considered a symptomatic treatment because of the systemic etiology of the disease in the given case. The use of the laser for treatment of this kind of gingival hyperplasia (in the case of epileptic patients) significantly delays the re-appearance of gingival hyperplasia. Only a disinfecting mouth solution was used in post-operative period for 8 days.



Figure 9.1.1: View of the gingival hyperplasia. The patient was given medicine for treating her epilepsy.

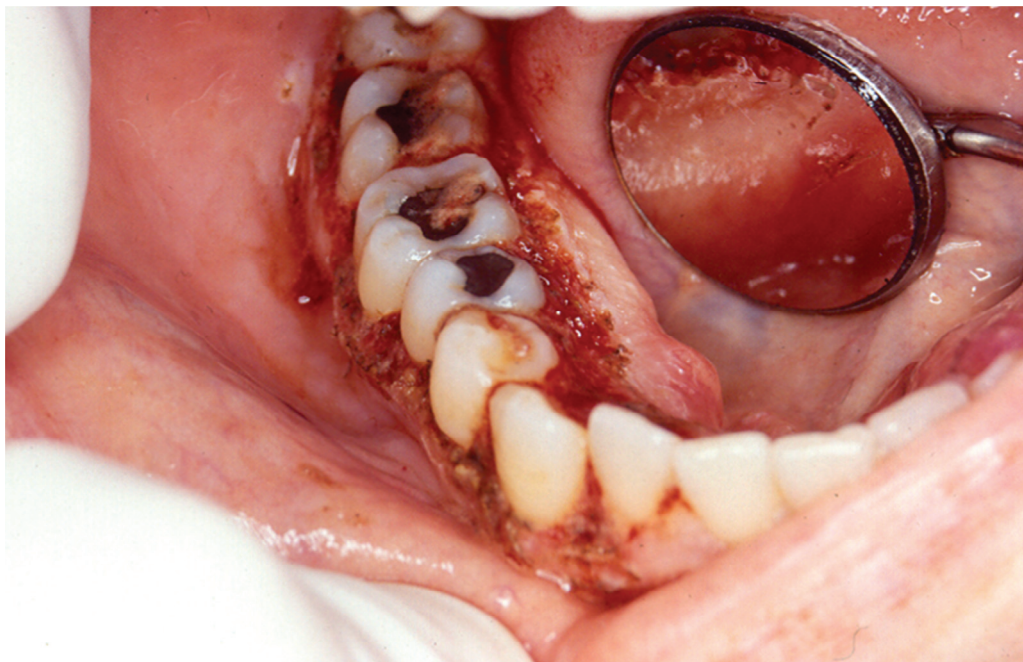


Figure 9.1.2: The gingival hyperplasia was excised by means of a CO₂ laser at focus, continuous and non-contact mode at 6 watts. An adapted metallic tool was inserted between the tooth gum and the enamel surface in order to protect enamel surfaces against any possible damage caused by the laser beam. At the end of the removal of the gingival hyperplasia, a gingival re-contouring was done for each tooth.



Figure 9.1.3: Labial view of the healing after 8 days.



Figure 9.1.4: Lingual view of the healing after 8 days.

Clinical case 2:

A 14-year-old Caucasian female asked for a gingivectomy because of the unaesthetic nature of her smile. She had a gingival hyperplasia (figure 9.1.5). The gingival hyperplasia was probably provoked by bad oral hygiene coupled with a hormonal disorder (puberty).

We decided to perform a gingivectomy on the concerned teeth. A local anaesthesia was given prior to the surgery. A CO₂ laser was used at focus, continuous and non-contact mode at 4 watts. First, an adapted metallic tool was inserted between the

tooth gum and the enamel surface. Next, an excision of the gum was completed, followed by a gingival re-contouring for each tooth (9.1.6). The gum healing was satisfactory after 8 days (figure 9.1.7).

Only a disinfecting mouth solution was used in the post-operative period for 8 days.



Figure 9.1.5: View of the gingival hyperplasia.



Figure 9.1.6: View of the surgical site at the end of the gingivectomy. A gingival re-contouring was done in order to re-draw an optimal design for the future gum. Only a disinfecting mouth solution was used in the post-operative period for 8 days.



Figure 9.1.7: View of the healed gum. Educating the patient about oral hygiene is primordial for avoiding any future recurrence of the gingival hyperplasia.

9.2 Gingivoplasty

Gingival plasty can be the indicated surgery for some aesthetic purposes, such as gingival re-contouring or papilla re-designing.

Laser irradiation conditions:

Mode	Super pulsed mode
Output power	10-20 Hz, 2 to 4 Watt
Focus/defocus mode	Focus mode. The tooth surface must be protected during laser by insertion of an adapted tool between the enamel and the tissue.
Surgery	Vaporization of hyperplasic tissues.

Clinical case:

A 14-year-old North African female asked for a gingivolasty because of the unaesthetic appearance of her papilla (probably due to an orthodontics treatment) (figure 9.2.1).

We decided to perform a gingivolasty on the concerned papilla. No local anesthesia was given prior to the surgery. A CO₂ laser was used at focus, super pulsed mode (10-20 Hz, pulse duration: 250 -350 µsec) and non-contact mode (figure 9.2.2). First, an adapted tool was inserted between the tooth gum and the enamel surface in order to protect the teeth against any possible damage by the laser beam. Next, the hyperplasic papilla was vaporized, followed by a gingival re-contouring for each tooth (9.2.3). The gum healing was satisfactory after 8 days (figure 9.2.4). Only a disinfecting mouth rinse solution was prescribed for the post-operative period.



Figure 9.2.1: View of the hyperplasic papilla.



Figure 9.2.2: View of the laser setting.



Figure 9.2.3: A gingival re-contouring was done at the end of the surgery. The surgery was performed without anesthesia.



Figure 9.2.4: The aspect of the healing was satisfactory after 8 days.

9.3 Frenectomy for periodontal purpose

In periodontics, frenectomy is indicated when the **frenulum** exerts tension on the gingival margin of teeth and/or interferes with the gingival recession process. The procedure is also employed when the **frenulum** prevents closure of a diastema during orthodontic therapy.

Aberrant fraenula insertion can be an important etiological factor in progressive gingival recession. When removing the fraenula, augmentation with the keratinized tissue is the treatment of choice (free gingival graft, laterally-positioned pedicle graft). When frenectomy is combined with graft, this surgical approach will also solve any aesthetic problem that may occur.

The laser beam is indicated for this kind of a surgery because of its haemostatic effect and its potential to induce the secretion of fibrins in the surgical site. The healed lased area is richer in fibrins and more resistant against trauma. Furthermore, it is not necessary to have a palatal graft for the increase of vestibular lengthening.

Laser irradiation conditions:

Mode	Continuous or super-pulsed mode
Output power	4 – 6 watts
Focus/defocus mode	Focus mode for the vaporization and the excision of the frenulum.
Surgery	Vaporization and excision of hyperplastic tissues.

Clinical case 1:

A 32-year-old Caucasian male had a significant and bad insertion of the frenulum (close to the cervical area of the central incisor, figure 9.3.1). Due to the high risk of gingival receding, we decided to make an ablation of the lower insertion of this frenulum. A local anesthesia was given prior to the surgery. A CO₂ laser was used at focus, continuous and non-contact mode at 6 watts. An excision of the fraenulum was performed. The gum healing was not complete after 7 days (figure 9.3.2) or after 12 days (figure 9.3.3). The gum aspect was satisfactory 3 weeks after surgery. The post-op control (after 2 months) showed a fibrous and attached aspect of the healed area (figure 9.3.4).

The use of the laser beam for this kind of a treatment offers several advantages, mostly due to the secretion of fibrins in the first 24 hours of the post-op period. The fibrins layer will cover the wound area during the healing period. The secretion will offer a fibrous layer to the newly formed attached mucosa, which is very important in periodontal surgeries.



Figure 9.3.1: The frenulum had a bad insertion (very close to the cervical gum). The risk of quick gingival receding was discussed. We decided to make a partial frenectomy in order to allow the formation of a new attached gum and avoid gingival receding.

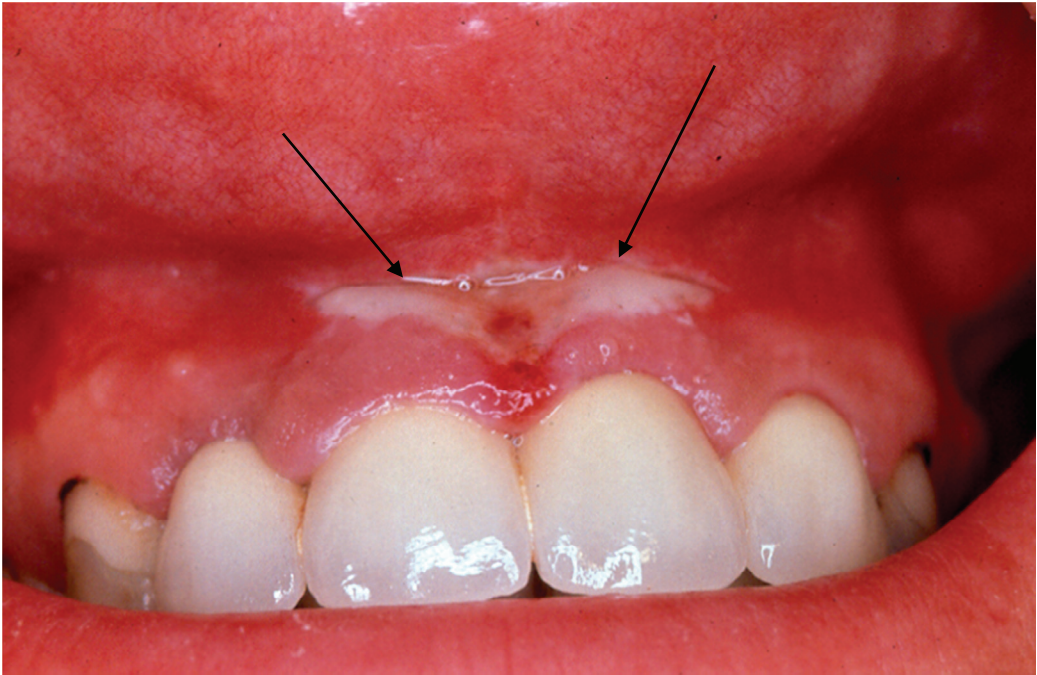


Figure 9.3.2: View of the surgical site at 7 days. The secreted fibrins are still covering the wound and clearly visible (arrows = white/ grey area). The healing process was not yet over.



Figure 9.3.3: View of the surgical site at 12 days. The presence of fibrins in some places of the healed surgical site can be observed. The healing process was not completely over.

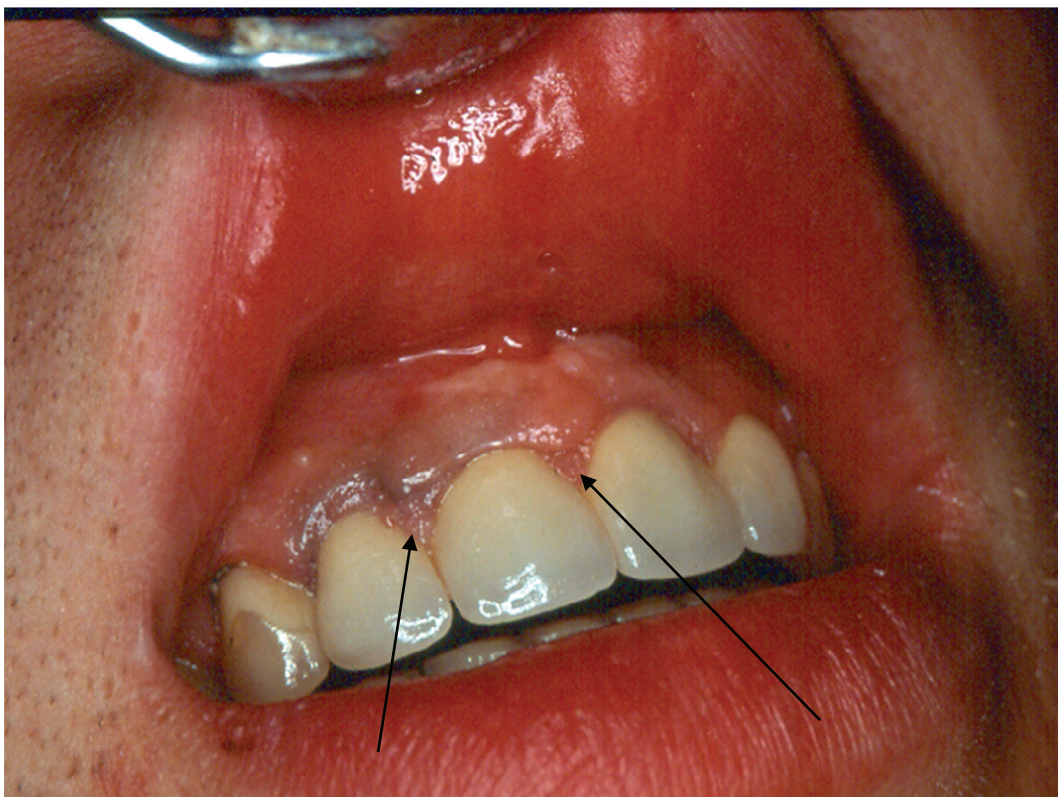


Figure 9.3.4: View of the healed surgical site at 2 months. The healed gum seems to be attached and healthy. The regeneration of new papillae at different locations (see arrows) can be observed. The results were satisfactory.

Clinical case 2:

The patient was an 11-year-old Caucasian female. Due to the high risk of gingival receding because of the bad insertion of the frenulum (figure 9.3.5), we decided to make an ablation of the lower insertion of this frenulum. A local anesthesia was given prior to the surgery. A CO₂ laser was used at focus, continuous and non-contact mode at 6 watts. An excision of the fraenulum was performed (figure 9.3.6). The gum healing was satisfactory after 2 weeks (Figure 9.3.7).

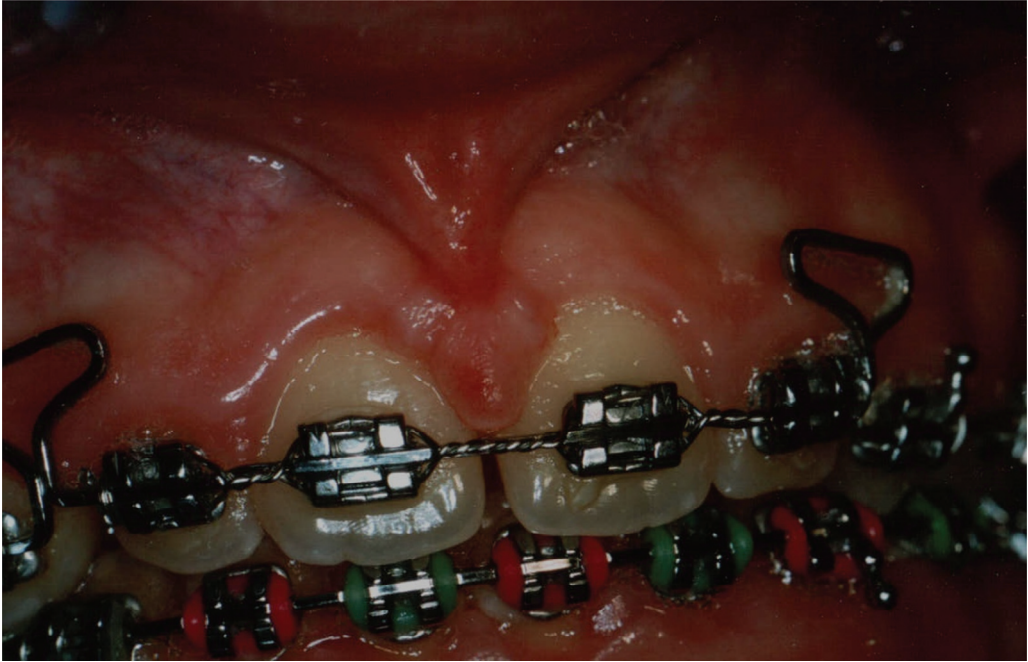


Figure 9.3.5: The frenulum had a bad insertion (very close to the cervical gum). We decided to make a partial frenectomy in order to allow the formation of a new and attached mucosa and avoid an eventual gingival receding.



Figure 9.3.6: View of the surgical site at the end of the surgery. The lip part of the flap was sutured to avoid an eventual rebound and a bad reattachment of the frenulum.



Figure 9.3.7: View of the healed surgical site at 2 weeks. The healed gum seemed to be attached and healthy. The results were satisfactory.

9.4 Vestibular deepening (increase of the attached gum)

The presence of an attached gum is important to avoid quick gum receding. Usually, a minimum of 4 mm of keratinized and attached gum is expected.

The fibrin secretions induced by the use of the laser in oral surgery are an important factor in assuring an attached and resistant gum at the surgical site. The use of a laser in the surgery of vestibular deepening makes this kind of surgery easy and simple. Furthermore, the use of the laser beam for vestibular lengthening prevents needing to use palatal grafts.

Laser irradiation conditions:

Mode	Super-pulsed or Continuous mode
Output power	4 watts
Focus/defocus mode	Focus mode
Surgery	Incision of oral soft tissues.

Clinical case 1:

A 12-year-old Caucasian male had an important and a bad insertion of the lateral frenulum (close to the cervical area of the first premolars (figure 9.4.1). Due to the high risk of gingival receding, we decided to ablate the frenulum. A local anesthesia was given prior to the surgery.

The procedure called “Namour I” was performed. The CO₂ laser was used at focus, continuous and non-contact mode at 4 watts. An excision of the fraenulum was done (figure 9.4.2). A suture was made only for the lip part of the wound in the aim to avoid an eventual rebound and a reattachment of the frenulum. The rest of the wound was left to heal without suturing.

The gum healing was not complete after 10 days (figure 9.4.3). The aspect of the attached gum was satisfactory 2 weeks after surgery (Figure 9.4.4). The main advantage of the use of laser for this kind of a surgery (“Namour I”) is the non-necessity to have a palatal grafts, which is highly appreciated by patients.



Figure 9.4.1: The frenulum had a bad insertion (very close to the cervical areas of premolars). We decided to make a complete excision of the frenulum in order to allow the formation of a new attached gum and avoid an eventual gingival receding.



Figure 9.4.2: View of the surgical site at the end of the surgeries. The procedure called “Namour I” was performed. The CO₂ laser was used at focus, continuous and non-contact mode at 4 watts. An excision of the fraenulum was done. A suture was made only for the lip part of the wound in the aim to avoid an eventual rebound and a reattachment of the frenulum. The rest of the wound was left to heal without suturing.



Figure 9.4.3: View of the surgical site at 10 days. The sutures were removed. The presence of fibrins was observed in some places of the healed surgical site. The healing process was not completely over.



Figure 9.4.4: View of the healed surgical site at 2 weeks. The healed gum seems to be attached and healthy. The results were satisfactory.

Clinical case 2:

A 46-year-old Caucasian female had a loss in the attached gum area (1mm in some areas, figure 9.4.5). Due to the high risk of gingival receding, we decided to make a vestibular deepening. A local anesthesia was given prior to the surgery. A CO₂ laser was used at focus, continuous and non-contact mode at 4 watts.

The procedure called “Namour II” was performed. An incision of the flap was made at the border of the attached gum (figure 9.4.6). The mandible bone was completely exposed. A borderline (3 mm) of burned bone was drawn on the surface of the bone by the laser beam at 2 watts in focus and continuous mode (Fig. 9.4.7). The aim of this borderline (burned bone) was to stop any possibility of muscle reattachment because of the long period of time needed for the healing of the burned bone area. The carbonization was kept at the bone surface. The sutures were made below the burned bone area (figure 9.4.7). There was no need to have a palatal graft. The flap was sutured to the periost (Fig. 9.4.7).

The healing was complete after 6 weeks (figure 9.4.8). The main advantages of the use of laser for this kind of surgery protocol (“Namour II”) are the simplicity of the surgical procedure and the non-necessity to have palatal grafts, which is highly appreciated by patients. The post-op control after 10 years was satisfactory (Fig. 9.4.9).

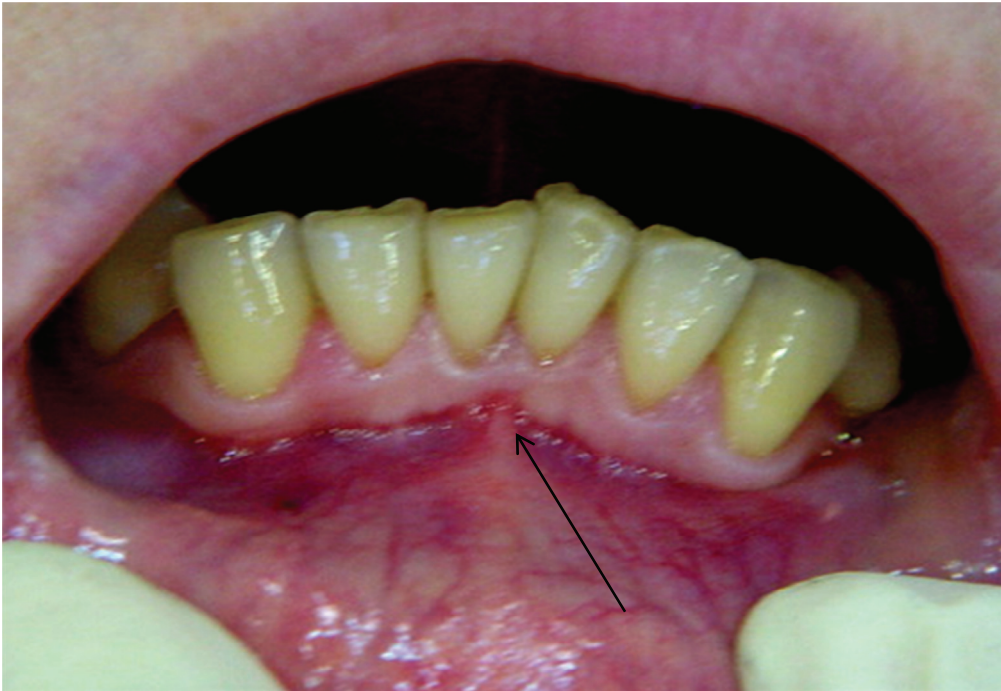


Figure 9.4.5: The frenulum had a bad insertion (very close to the cervical areas). A loss in the attached gum area (1mm in some areas) was noticed. It was decided to make a vestibular deepening in order to avoid an eventual quick gingival receding.



Figure 9.4.6: View of the surgical site at the end of bone exposition. The flap involved the periost. The bone surface was totally exposed.



Figure 9.4.7: View of the surgical site at the end of the surgery. The procedure called “Namour II” was performed. A border line of burned bone (± 3 mm) was drawn on the surface of the bone by laser beam in the aim to stop any possibility of muscle reattachment (rebound) because of the long period of time needed for the healing of the burned bone area. The carbonization was kept at the bone surface. The flap was sutured to the periost below the burned bone area. There was no need to have a palatal graft. An antibiotic, anti-inflammatory, analgesic and a disinfecting mouth rinse solution were prescribed for the post-operative period.



Figure 9.4.8: View of the healed surgical site at 6 weeks.



Figure 9.4.9: View of the surgical site at 10 years of post-op. The healed gum seemed to be attached and healthy. The results were satisfactory

9.5 Treatment of acute infection of peri-coronal tissues

When the gum is still covering the distal area of the coronal part of the tooth (mainly in the case of wisdom teeth), repetitive infections can occur due to the difficulty cleaning the pocket between the tooth and the distal gum. These repetitive infections can lead to an acute infection of the peri-coronal tissues. In order to give an adapted treatment (healing of the infection), it is advised to excise the distal gum to allow for better cleaning of the gingival pocket. The laser beam is able to ablate the excess of the gum, decontaminate the infected site (by heat generated during laser surgery), and offer a good healing quality to the future gum. It is important and highly recommended to protect the tooth surface during the surgical procedure in order to avoid harming the enamel surface.

Laser irradiation conditions:

Mode	Super-pulsed mode
Output power	2 watts, 10 – 20 Hz; pulse duration: 250 μ sec
Focus/ defocus mode	Focus mode
Surgery	Incision and ablation of the gum.

Clinical case:

A 19-year-old Caucasian female asked for treatment of the repetitive infection of the distal part of the wisdom tooth (figure 9.5.1). The X-ray showed that the tooth had a total eruption and was not covered by the bone. A local anesthesia was given. Before using the laser beam, an adapted tool was inserted between the gum and the tooth surface. Next, an incision of the hyperplasic gum was made, followed by a gingival re-contouring of the wisdom tooth (figure 9.5.2). An analgesic and a disinfecting mouth rinse solution were prescribed for the post-operative period. Recommendations were made for an adapted oral hygiene. The gum healing was satisfactory (figure 9.5.3).

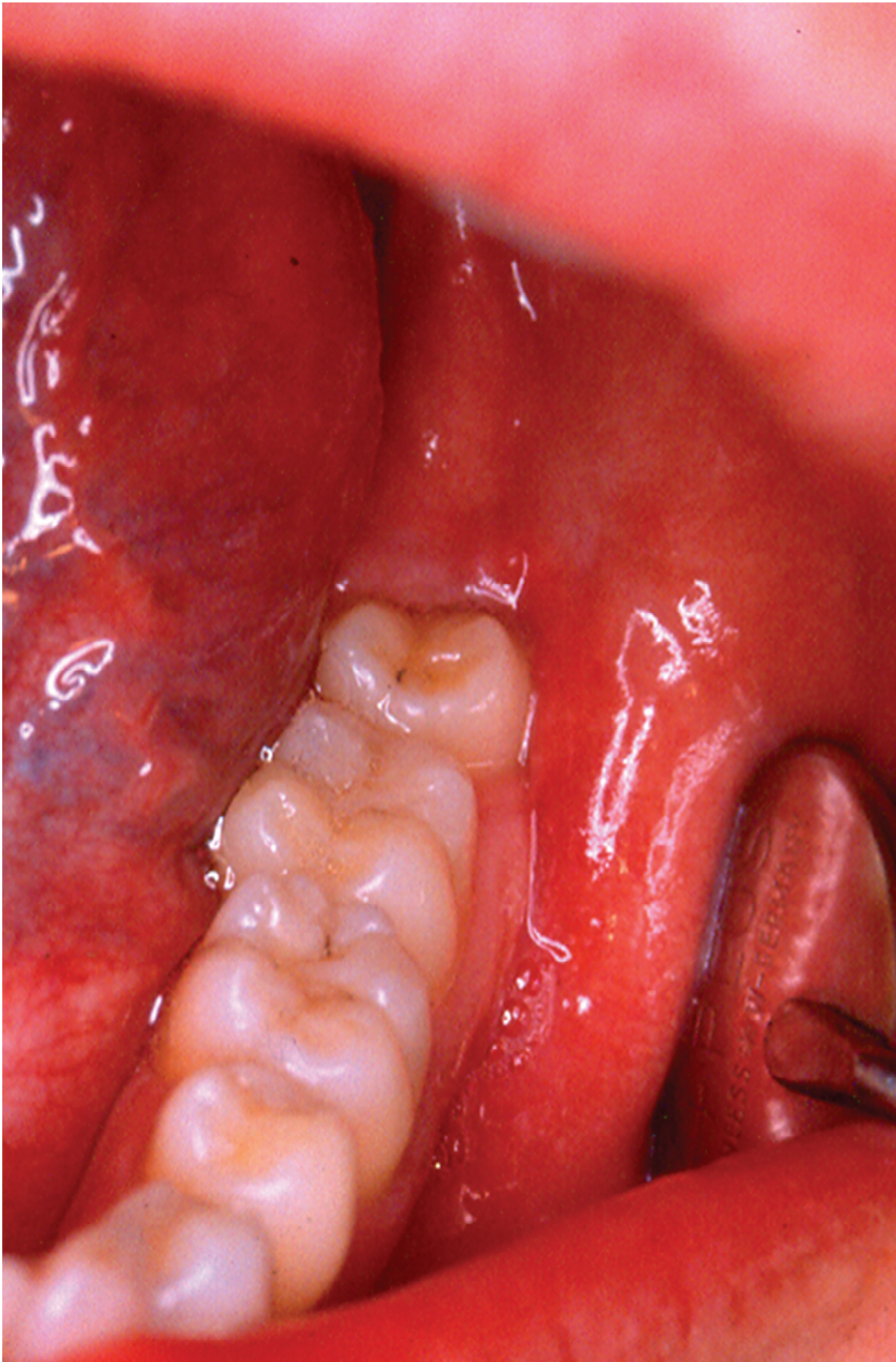


Figure 9.5.1: View of the gum covering the distal part of the wisdom tooth.

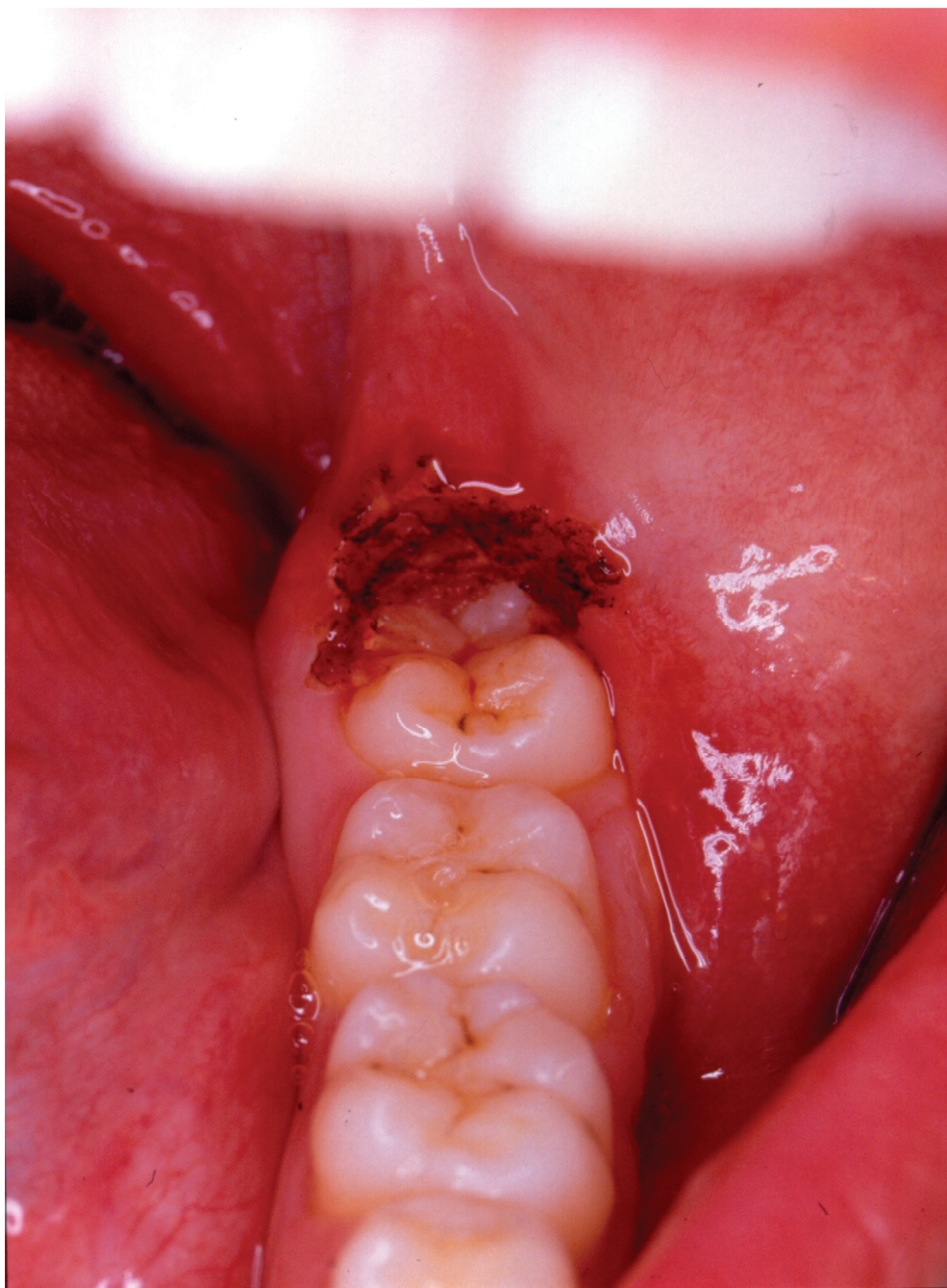


Figure 9.5.2: Before using the laser beam, an adapted tool was inserted between the gum and the tooth surface. Next, an incision of the gum was made, followed by a gingival re-contouring of the distal part of the wisdom tooth. An analgesic and a disinfecting mouth rinse solution were prescribed for the post-operative period. Recommendations were made for an adapted oral hygiene.

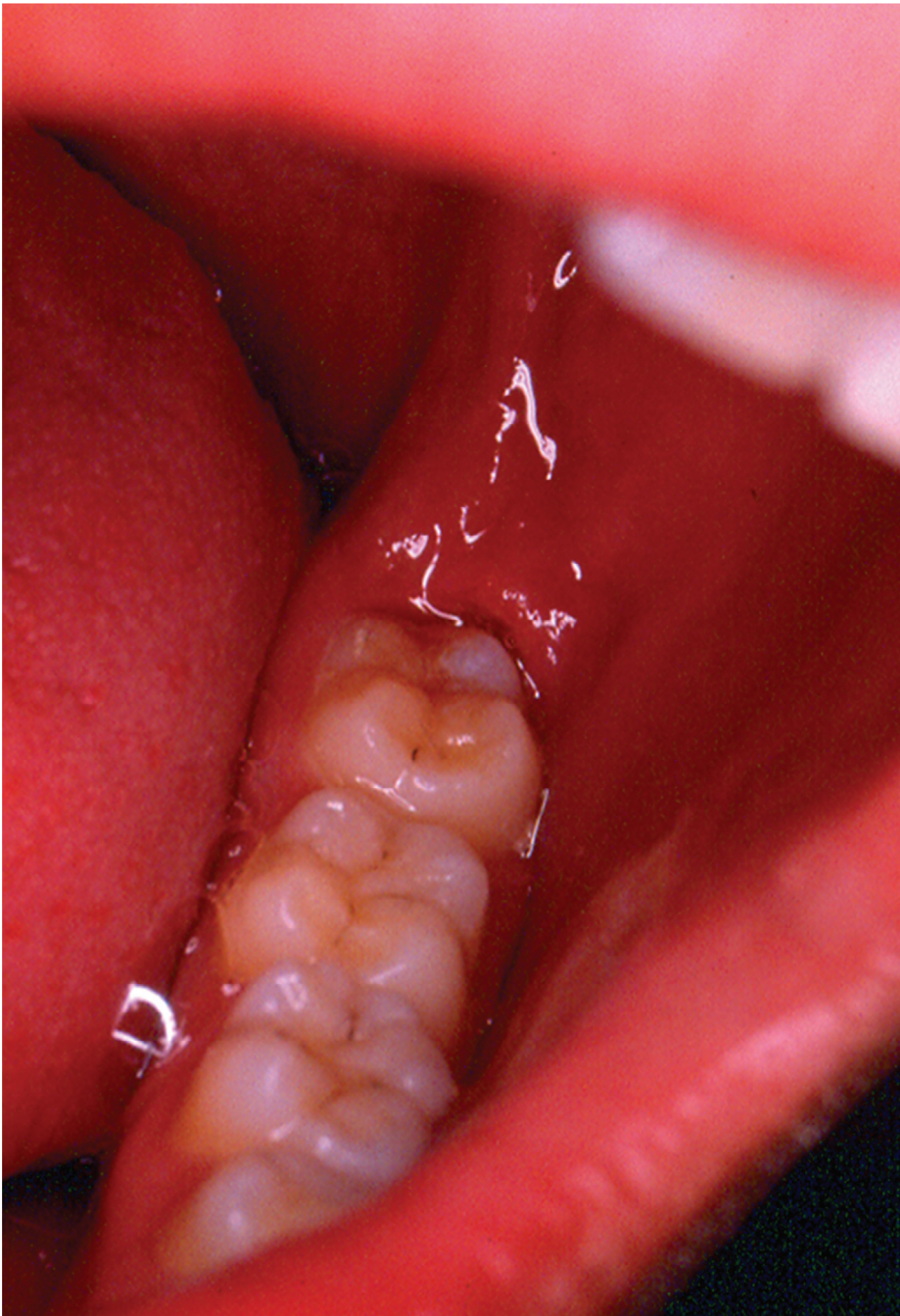


Figure 9.5.3: View of the tooth at 2 weeks. The gum was healed. The patient was able to clean the distal part of the tooth without difficulty. Therefore, the repetitive infections would likely be avoided.

9.6 Distal wedge

A high position of the gum in the distal area of the posterior tooth can provoke repetitive infections. This can be due to the difficulty that a patient encounters when cleaning the bottom of the distal sulcus. It is the depth of the gingival pocket that causes the difficulty. Therefore, repetitive peri-coronal infections can occur. A practitioner can perform a distal wedge surgery to avoid these infections. The aim of the distal wedge surgery is to remove the excess of the gum, reduce the sulcus depth, and allow the patient to correctly clean the concerned area.

Laser irradiation conditions:

Mode	Super-pulsed mode
Output power	2 watts, 20 – 30 Hz; pulse duration: 200 μ sec
Focus/ defocus mode	Focus mode
Surgery	Incision and vaporization of the gum.

Clinical case:

A 44-year-old Caucasian female asked for a treatment of the repetitive infection of the distal part of the second lower right molar (figure 9.6.1). The hyperplasic gum did not allow the patient to easily clean the distal gingival pocket. A local anesthesia was given prior to the surgery. Before using the laser beam, an adapted tool was inserted between the gum and the tooth surface. Next, a vaporization of the hyperplasic gum was done, followed by a gingival re-contouring of the concerned tooth (figure 9.6.2). An analgesic and a disinfecting mouth rinse solution were prescribed for the post-operative period. Recommendations were given to the patient for an adapted oral hygiene. The gum healing was satisfactory after 8 days (figure 9.6.3).



Figure 9.6.1: View of the distal and hyperplastic gum.

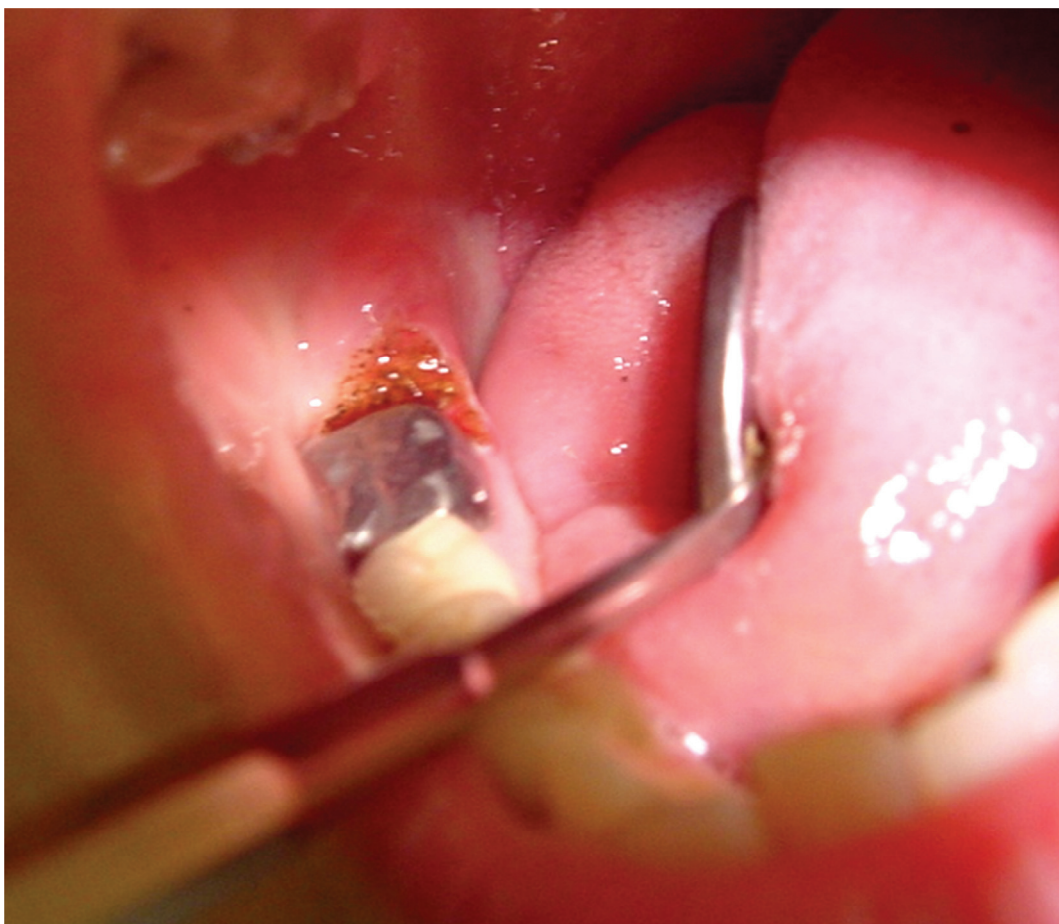


Figure 9.6.2: The laser beam was used to vaporize the hyperplastic gum. An adapted metallic tool was inserted between the gum and the distal part of the tooth in order to avoid any overheating of the tooth surface by the laser beam. The depth of the distal sulcus was reduced until ± 1 mm. A gingival re-contouring was done at the end of the surgery for the distal, lingual and labial parts of the concerned tooth. An analgesic and an oral mouth rinse solution were prescribed for the post-op period. Recommendations were given to the patient for an adapted oral hygiene.



Figure 9.6.3: The reduction of the gum level allowed the patient to easily clean the distal area. The healed gum was rich in fibrins secreted by the lased wound. The healing was satisfactory.

Different lasers may be indicated for the field of implant dentistry. Lasers can be used in periimplantitis treatment (either by using the flap method or not) for several purposes: the decontamination of the implant surface, the management of the soft tissues around implants, the anti-inflammatory effect of the laser beam, and bio-stimulation of the bony and gingival affected area.

Multiple *in vitro* studies have been performed to evaluate the implant surface changes, as well as temperature increase measurements after laser irradiation of the implant surfaces.

It has been demonstrated that the CO₂ laser does not damage the implant's surface. On the other hand, for some of the other laser wavelengths, different changes and melting have been found on the implant surface caused by the laser beam irradiation. It has also been noted that CO₂ laser irradiation of implants, under specific irradiation conditions, does not significantly increase the temperature of the implant body and does not negatively influence the attachment of the fibroblasts or osteoblasts cells on the implant surface.

In the periimplantitis treatments, the CO₂ laser beam can perform an implant surface decontamination (bacteria reduction) before augmentative procedures for bone regeneration. The implant decontamination showed that this laser wavelength may lead to new bone formation and re-Osseo-integration, especially 5 to 8 weeks post-operatively.

The clinical efficacy of the diode laser (810 nm at 1 to 1.5 W) used on patients with periodontal disease or periimplantitis including surface decontamination of implants was demonstrated, in addition to conventional procedures (no flap procedure).

During the treatment of periimplantitis, the sub-gingival laser treatment resulted in a significant decrease of the initial level of periodontal pathogens. In a clinical situation with peri-implant bone resorption, the decontamination and cleaning of implant surfaces are required for the re-integration of the exposed surface implant. The super-pulsed CO₂ laser combined with citric acid and hydrogen peroxide is effective for the cleaning and reestablishment of the atomic composition and oxide structure of the contaminated titanium surfaces.

10.1 Gingivectomy & Gingivoplasty

For gingivectomy, the laser beam is only used for the incision and cutting. The beam offers a bloodless surgery. The healed gum is rich in fibrins, which are secreted during the first 24 hours after laser surgery.

Laser irradiation conditions:

Mode	Super-pulsed mode for gingivoplasty and for peeling
Output power	2 W; 10 – 50 Hz; pulse duration : 200 - 250 μ sec.
Focus/defocus mode	Focus mode for incision; defocus mode for peeling.
Surgery	Demarcation by laser beam of the cervical limit of the gingivectomy. Incision of the gum. Gingival peeling and gingival contouring at the end of the surgery

Clinical case:

A 74-year-old Caucasian female asked for a periimplantitis treatment (figure 10.1.1). We decided to perform a gingivectomy followed by a gingivoplasty. A local anesthesia was given prior to the surgery. After a conventional removal of the tartar on the implant surfaces, a CO₂ laser was used at focus, super pulsed mode (10 Hz, pulse duration: 250 μ sec) and non-contact mode.

First, an adapted tool was inserted between the tooth gum and the implant surface. Next, a vaporisation of the hyperplasic gum was done, followed by a gingival re-contouring for each implant (figure 10.1.2). Only a disinfecting mouth rinse solution was prescribed for the post-operative period. Recommendations were made for an adapted oral hygiene. The gum healing was satisfactory after 8 days (figure 10.1.3).

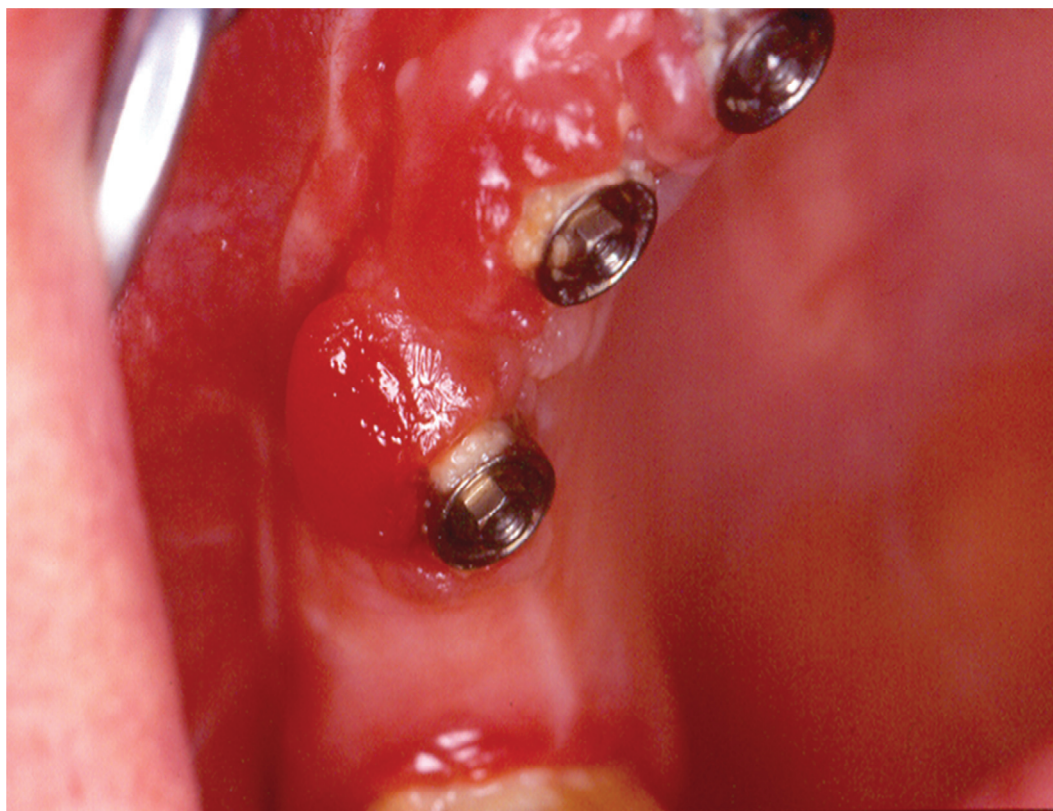


Figure 10.1.1: View of the periimplantitis. The tartar existed on the cervical parts of implants. The patient found it difficult to clean around the implants.

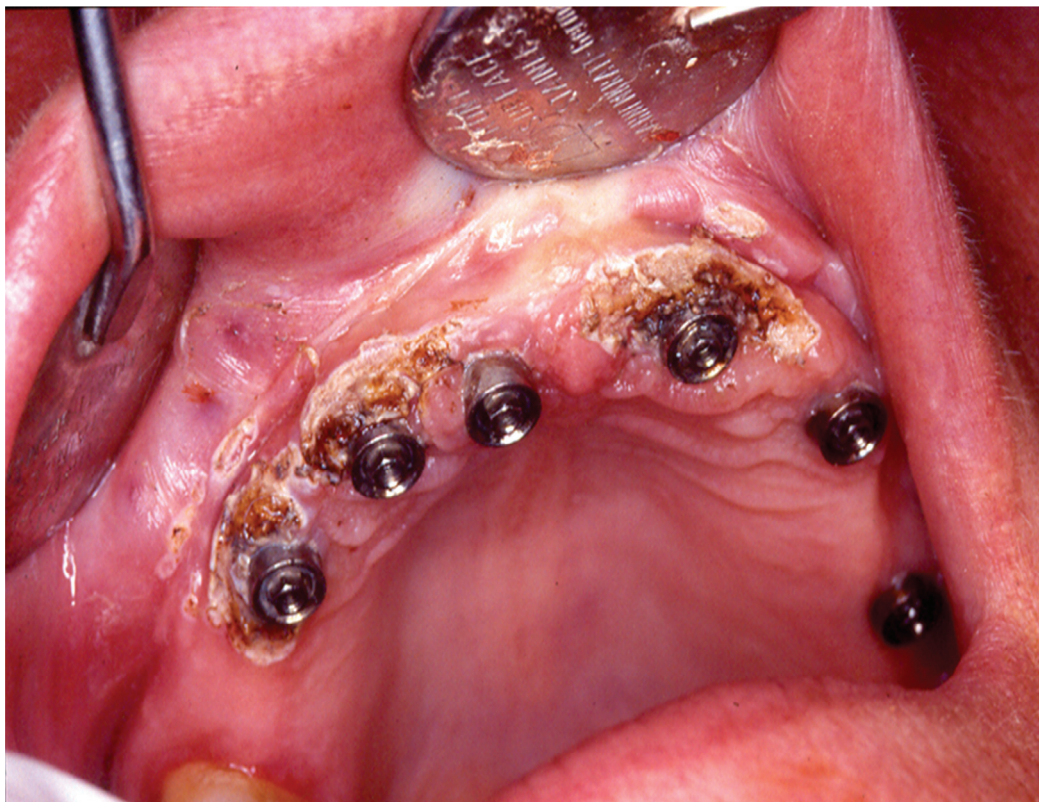


Figure 10.1.2: The tartar was removed conventionally with adapted tools for the implant surfaces. The hyperplasic gum was vaporized by a CO₂ laser beam followed by a gingival re-contouring for each implant. To avoid an eventual overheating of implant surfaces and surrounding bone, the implant surfaces were protected by the insertion of an adapted metallic tool between the gum and implant surfaces. Only a disinfecting mouth rinse solution was prescribed for the post-operative period. Recommendations were made for an adapted oral hygiene.

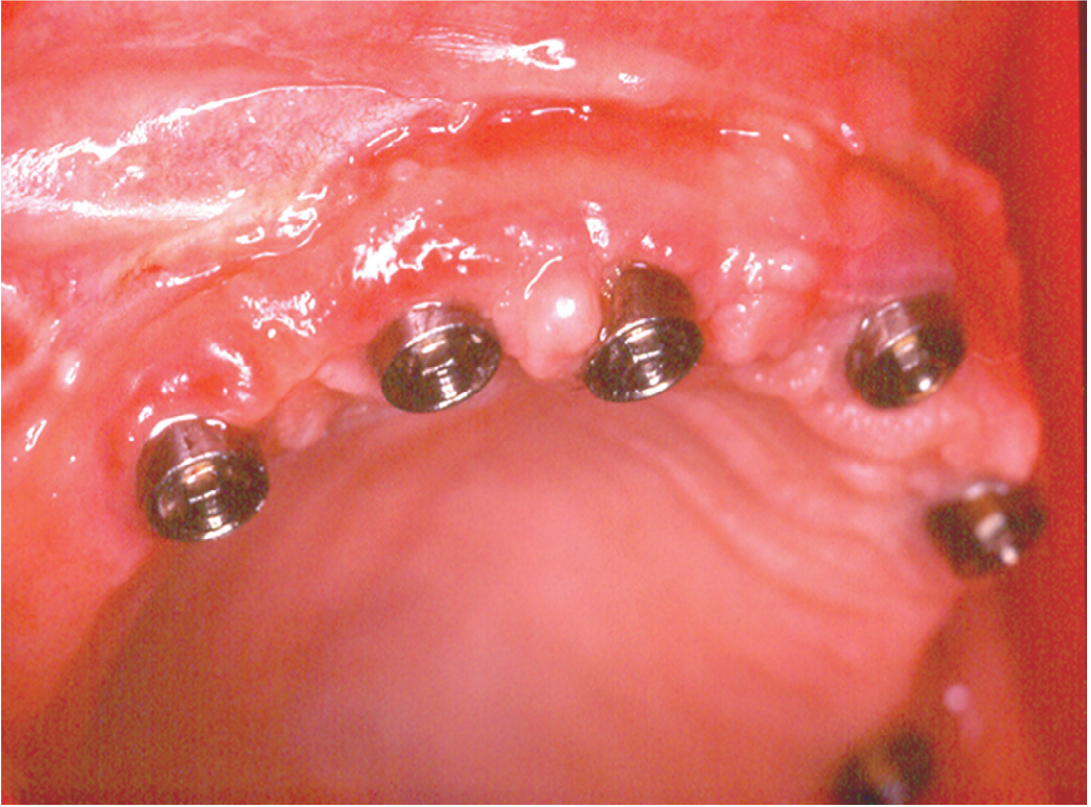


Figure 10.1.3: View of the healed gum. There was no gingival receding. The healing was satisfactory after 8 days.

10.2 Gingival remodeling

Gingival hyperplasia or small fibromatous tumors can cause some difficulties when cleaning prosthetic structures. Treatment should involve the removal of this kind of hyperplasia. The laser beam is helpful because of its ability to make a slight peeling of the soft tissues, the non-necessity to make sutures, and the quality of healing of the operated area (rich in fibrins and more resistant).

Laser irradiation conditions:

Mode	Super-pulsed mode
Output power	2W; 10 – 30 Hz, pulse duration: 200 -250 µsec.
Focus/ defocus mode	Focus mode
Surgery	Slight peeling of the fibromatous area.

Clinical case:

A 72-year-old Caucasian female asked for treatment for the repetitive infections at the level of the bar-connecting implants. The gum hyperplasia reduced the space between the implant's bar and the gum (figure 10.2.1). The patient had difficulty easily clean that area. The retention of food and biofilm formation caused multiple infections and periimplantitis. There was no need to use anesthesia. A CO₂ laser was used at focus, super pulsed mode (10 Hz, pulse duration: 250 µsec) and non-contact mode. A vaporisation of the hyperplasic gum by multiple superficial peelings was done, followed by a gingival re-contouring for each implant (figure 10.2.2). Only a disinfecting mouth rinse solution was prescribed for the post-operative period. Recommendations were made for an adapted oral hygiene. The gum healing was satisfactory after 8 days (figure 10.2.3).



Figure 10.2.1: View of the hyperplasic gum. The space between the gum and the bar-connecting implants was reduced, thereby making it very difficult to clean under the bar and around the implants.



Figure 10.2.2: View of the surgical site at the end of surgery. There was no need to use anesthesia. A CO₂ laser was used at focus, super pulsed mode (10 Hz, pulse duration: 250 μ sec) and non-contact mode. A vaporisation of the hyperplasic gum by multiple superficial peelings was done followed by a gingival re-contouring for each implant. Only a disinfecting mouth rinse solution was prescribed for the post-operative period. Recommendations were made for an adapted oral hygiene.



Figure 10.2.3: View of the healed gum 8 days after surgery. The space between the gum and the bar allows for an easy cleaning of the area.

ORAL AESTHETIC SURGERY

In oral aesthetic surgery, laser beams can offer many advantages. The secretion of fibrin by lased wounds offers a better quality and aspect (healthy, fibrous and attached gum) to the healed area. The selective absorption of the laser beam by tissues can be helpful for the removal of the colored matter.

On the other hand, the CO₂ laser has no selective absorption by the colors of the tissues. Therefore, the irradiation conditions of this kind of laser should be adapted to the high absorption by the tissues.

11.1 Gingival tattoo

Mostly, the gingival tattoo can be caused by metallic projections during the drilling of the metallic matters (metallic crowns, amalgams, etc.). The gingival tattoo causes an unaesthetic aspect of the smile. Patients often ask about the possibility to remove these gingival discolorations. The excisional removal of tattoo can produce gingival receding as a consequence, which is undesirable and causes a more important unaesthetic problem.

Laser beams can be helpful for the removal of the gingival tattoo. The use of laser beams with high affinity and selective absorption for the dark colors can be helpful. The CO₂ laser beam can be used for this kind of a treatment under certain conditions. The CO₂ laser irradiation should be set up to generate the minimum possible amount of heat during gingival tattoo ablations. It is preferable to select the shortest pulse duration possible in the super pulsed mode, and reduce the maximum number of pulses per second (Hz). In this way, less heat will be generated, and gingival receding can be avoided. When removing the tissues containing the tattoo pigments, it is mandatory to avoid exposing the surface of the tooth (enamel, root cement) or the implant surface. It is advised to avoid cutting and entirely removing the cervical gum in order to avoid any gingival receding and allow for a complete recovery of the cervical gum.

Laser irradiation conditions:

Mode	Super-pulsed mode
Output power	2W; 10 Hz, pulse duration: 200 μ sec.
Focus/defocus mode	Focus mode
Surgery	Slight peeling of the pigmented area. Avoiding removing all the cervical gum in one session. Avoiding exposing the dental or implant surface during tattoo removal.

Clinical case:

A 32-year-old Caucasian female asked for a removal of a gingival tattoo (figure. 11.1.1). Local anesthesia was given. A CO₂ laser was used at focus, super pulsed mode (5 Hz, pulse duration: 200 μ sec) and in a non-contact mode. A vaporization of the pigmented area was done by multiple superficial peelings (figure 11.1.2). Only a disinfecting mouth rinse solution was prescribed for the post-operative period. Recommendations were made for an adapted oral hygiene. The gum healing was satisfactory after 15 days (figure 11.1.3). No gingival receding was noticed. Six weeks after surgery, the prosthetic rehabilitation (aesthetic crown) of the tooth was done (figure 11.1.4).



Figure 11.1.1: View of the unaesthetic aspect of the gum.



Figure 11.1.2: The pigmented area was vaporized by multiple slight peelings. Total removal of the cervical gum was avoided to allow gum regeneration. The root surface was accidentally exposed during surgery (see arrow). A disinfecting mouth rinse solution was prescribed for the post-op period.



Figure 11.1.3: View of the healed gum. The gingival receding was only noticed at the level of the ablated area in which the root surface was exposed accidentally (see arrow). The aesthetic quality of the regenerated gum was noticed. In order to obtain a gum rebound, it was recommended to the patient to have an excellent and adapted oral hygiene. Patient should clean the exposed root to allow a complete gingival rebound.

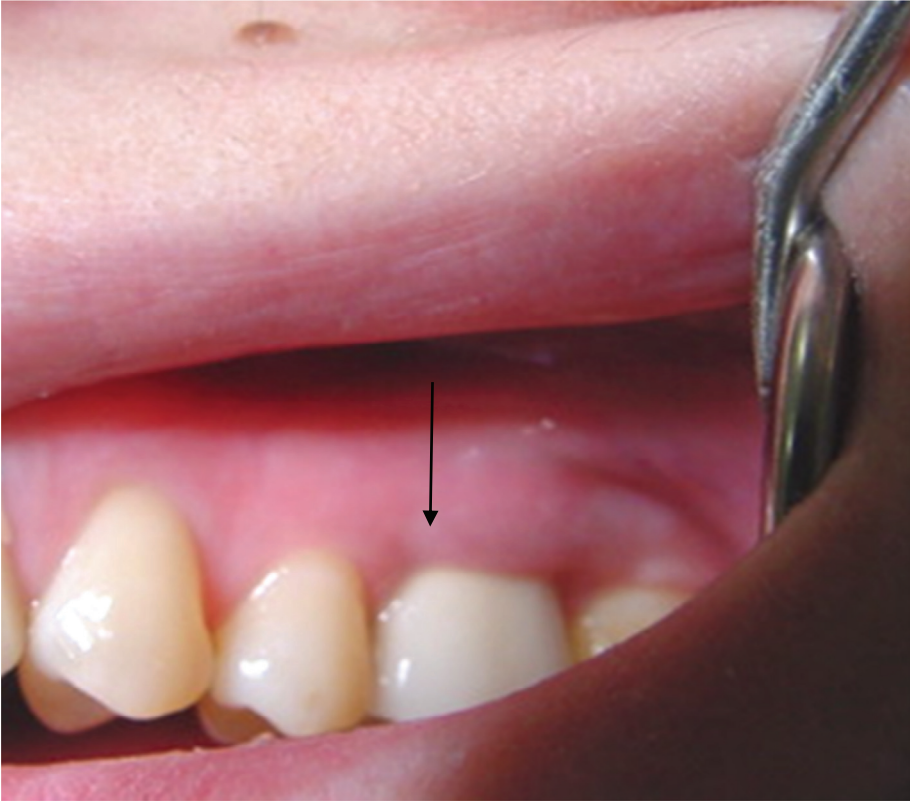


Figure 11.1.4: View of the gum after the tooth rehabilitation at 8 weeks after surgery. The regeneration of the cervical gum was noticed (see arrow).

11.2 Gingival pigmentation (Melanin) removal

Several wavelengths have been proposed for removing melanin pigmentation. It has also been proposed that the CO₂ laser beam in super pulsed mode is an effective and safe method for the elimination of gingival melanin pigmentation. The pigmented areas can be easily removed by multiple passages of slight peeling.

In the literature, it is mentioned that a small percentage of clinical cases can have a recurrence. A partial re-pigmentation can reappear during the 24 months of follow-up. The rebound in the gum re-pigmentation may be due to the incomplete removal of melanin during the surgical procedure.

Laser irradiation conditions:

Mode	Super-pulsed mode
Output power	2 W; 30 to 50 Hz, pulse duration: 200 μ sec.
Focus/defocus mode	Focus mode
Surgery	Slight peeling of the pigmented area.

Clinical case:

A 24-year-old North African female asked for an aesthetic solution against the gingival melanin pigmentation (Fig. 11.2.1). A local anesthesia was given. A CO₂ laser was used at focus, super pulsed mode (50 Hz, pulse duration: 200 μ sec) and non-contact mode. A vaporization of the pigmented area was done by multiple superficial peelings. This surgery can be considered complete after removal of all the pigmented layers of the concerned gum (Figure 11.2.2). An analgesic and a disinfecting mouth rinse solution were prescribed for the post-operative period. Recommendations were made for an adapted oral hygiene. The gum healing and the aesthetic aspect were satisfactory after 15 days (Figure 11.2.3).



Figure 11.2.1: View of the pigmented gum.



Figure 11.2.2: The pigmented layer of the gum was removed by multiple passages of slight peeling. A CO₂ laser was used at focus, super pulsed mode (50 Hz, pulse duration: 200 μ sec) and non-contact way. A vaporization of the pigmented area was done by multiple superficial peelings. The surgery can be considered complete after removal of all the pigmented layers of the concerned gum. The cervical gum cannot be irradiated in order to avoid any possibility of gingival receding. An analgesic and a disinfecting mouth rinse solution were prescribed for the post-operative period. Recommendations were made for an adapted oral hygiene.



Figure 11.2.3: View of the gum healing. The aesthetic aspect was satisfactory after 15 days.

11.3 Aesthetic corrections of flabby lips

For different etiologies, the design and the shape of the lips can be altered. Laser irradiations can be helpful for the treatment of this kind of unaesthetic lip condition. Effectively, the laser beam will provoke the secretion of fibrins at the lased wounds. This secretion will give a firm content to the healed area that can improve the aesthetic aspect of the lips. Furthermore, the excess of the flabby area can be easily removed.

Laser irradiation conditions:

Mode	Super-pulsed mode
Output power	2 W; 30 to 50 Hz, pulse duration: 200 μ sec.
Focus/defocus mode	Focus mode
Surgery	Excision of the flabby areas. No sutures in order to avoid any anatomic distortion or loss in the lips' symmetry.

Clinical case:

A 72-year-old Caucasian female asked for an aesthetic solution to the flabby aspect of her lips (Fig. 11.3.1). A local anesthesia was given. A CO₂ laser was used at focus, continuous mode (6 W) and in a non-contact way. The excision of the flabby areas was performed, followed by a correction of the lips' shape. No sutures were made in order to avoid any distortion in the lips' anatomy or any loss in the symmetry of the upper lip (Figure 11.3.2). An analgesic, antibiotic, anti-inflammatory, and a disinfecting mouth rinse solution were prescribed for the post-operative period. Recommendations were made for an adapted oral hygiene. The gum healed after 2 weeks. The aesthetic aspect was satisfactory after 4 weeks (Figure 11.3.3).



Figure 11.3.1: View of the unaesthetic aspect of the flabby upper lip (see circle).



Figure 11.3.2: After a local anesthesia, the CO₂ laser was used at focus, continuous and non-contact mode (6 W). The excision of the flabby areas was completed, followed by a correction of the upper lip's shape. No sutures were made in order to avoid any distortion in the lips' anatomy or loss in the symmetry of the lip. An analgesic, antibiotic, anti-inflammatory, and a disinfecting mouth rinse solution were prescribed for the post-operative period. Recommendations were done for an adapted oral hygiene.



Figure 11.3.3: View of the aesthetic and satisfactory aspect of the upper lip after 4 weeks of post-op. The results were satisfactory.

ROUND TABLE DISCUSSION WITH INTERNATIONAL EXPERTS

The following is a round table discussion with international experts in the dental laser field:

1. **Question:** We have tried to examine and discuss some clinical applications of the CO₂ laser in current oral surgery. In our opinion, indications of such a surgical approach are large and probably (surely) larger than those described here. In your experience, with the exception of maxillo-facial surgery which was not the main objective of this discussion, what are the other indications that were not discussed?
 - *John FRAME:* The CO₂ laser is suitable for excising most benign lesions which require removal and for excising pre-malignant lesions of the oral mucosa, provided they are not too extensive in size.
 - *Isao Ishikawa:* One of the important characteristics of the CO₂ laser is sterilization. Without causing carbonization, the infected area can be sterilized by CO₂ irradiation with defocused mode irradiation. This may accelerate the wound healing in oral and periodontal minor surgery.
 - *Hong Sai LOH:* Laser-assisted prosthodontic procedures, e.g., excision of intra-oral lesions; removal of vascular and pigmented lesions; laser applications in apical surgery; laser assisted uvulopataloplasty for snoring; laser facial resurfacing for facial aesthetics; and laser disinfections.
 - *Lynn Powell:* Other applications might include decay prevention.
2. **Question:** What are the main advantages regarding CO₂ laser use as compared with conventional methods (bistouries, electric bistouries, etc.)?
 - *John FRAME:* The advantages are less bleeding, good visibility during surgery, no need to suture a wound or apply a dressing, and good healing after surgery with little scarring.

- *Isao Ishikawa*: The main advantage regarding the CO₂ laser in periodontal surgery is no bleeding. During periodontal surgery, including frenectomy and gingivectomy, there is no bleeding. This is especially advantageous to patients who have viral infections, such as Hepatitis B and C and AIDS.
 - *Hong Sai LOH*: Laser surgery reduces instrumentation and therefore increases surgical access; favorable bio-interactions reduces pain, bleeding, and swelling; less surgical scarring and contractions; less damage to surrounding tissues; patient-friendly and repeatable without many side effects; could have a biostimulatory and immunological response.
 - *Lynn Powell*: The advantages of laser surgery include: little or no bleeding at the time of surgery, little or lack of swelling, little or reduced pain following surgery post-operatively.
3. Question: What could be the disadvantages of this technology in an oral environment?
- *John FRAME*: The disadvantages are: if the soft tissue lesion being excised is overlying the bone, then there is a risk of thermal damage to the bone. Another potential disadvantage is that the practitioner may have only limited experience and skills in using the CO₂ laser.
 - *Isao Ishikawa*: The disadvantage of the CO₂ laser in the oral environment is that CO₂ laser irradiation is not suitable to hard tissue, including enamel and cementum. In case of irradiated enamel, surface melting and surrounded microcracking are prominent.
 - *Hong Sai LOH*: The disadvantage is primarily in equipment costs and perhaps the need to have several types of lasers to deal with different tissue types in the mouth (e.g., soft tissues, bone, and teeth).
 - *Lynn Powell*: Must be careful around teeth. Due to the high absorption of the CO₂ by the enamel (tooth structure), there is a need to protect the teeth from possible damage. Also, lack of a flexible fiber.

4. Question: Which kind of alternative could you suggest for further treatment (example: other wavelengths)?
 - *John FRAME*: I prefer the CO₂ laser for most soft tissue surgery.
 - *Isao Ishikawa*: For the hard tissue treatment, Erbium YAG laser can be suggested.
 - *Hong Sai LOH*: CO₂ is perhaps the best laser, with its wavelength suited to the mucosa of the oral cavity; therefore, any other lasers would be just as good, as long as the wavelengths are close to that of the CO₂ laser. For chromophore-related conditions, then, other wavelengths are needed.
 - *Lynn Powell*: The CO₂ is a good soft tissue cutter, but there may be other lasers that are better coagulaters, such as the argon or Nd: YAG.
5. Question: In cases of oral disease, is a biopsy necessary? How would you manage it (bistouries, lasers)?
 - *John FRAME*: Biopsies should be performed as a routine for all soft tissue excised from the mouth. This confirms the diagnosis and is a medico-legal requirement.
 - *Isao Ishikawa*: If the involved lesion is from inflammation, biopsy is not always necessary.
 - *Hong Sai LOH*: Biopsy is a gold standard for diagnosis of any condition, and therefore should be performed. The laser beam produces minimal disruptions at the margins. Having completed that, the remaining lesional tissues can be then vaporized or excised.
 - *Lynn Powell*: Biopsies should be performed for lesions or diseases that require it for diagnosis. If the laser is used, then the pathologist needs to be informed because the borders will appear different than those from a scalpel.

6. Question: In your opinion, what could be the future in oral laser surgery?

- *John FRAME*: As the instrumentation becomes more compact and mobile and less expensive, then CO₂ laser surgery will become more widely used and accessible to all the dental practitioners.
- *Isao Ishikawa*: The CO₂ laser is effective for oral soft tissue. For the hard tissue treatment in periodontal surgery, Er:YAG laser is recommended, especially in subgingival scaling and debridement.
- *Hong Sai LOH*: The laser is certainly better than other thermal-energy related modalities like the cryoprobe and electrosurgery, in terms of post-operative effects. With dual or combined wavelengths, and the reduction of the size and cost of laser equipment, there would be an increased use of lasers in oral surgery.
- *Lynn Powell*: As lasers are developed that can perform multiple procedures (soft tissue, endodontics, pulpotomies, etc.) and if units become smaller, less costly and fiber delivery, then practitioners are more likely to buy and use lasers. Thus, they will be more likely to do oral laser surgery.

7. Question: What are your main recommendations for dental practitioners interested in starting to use the CO₂ laser technology in oral surgery?

- *John FRAME*: Recommendations are: take a course, observe and work with experienced users, and start with simple lesions before progressing to more extensive surgical procedures.
- *Isao Ishikawa*: Frenectomy, eliminations of melanin pigmentation and gingival hyperplasia are recommended.
- *Hong Sai LOH*: As in most countries, proper training and certification would be necessary for accreditation. Regular basic science and clinical courses should be taken. Forming a local society or study group and participating in laser congresses help increase a practitioner's awareness about the latest developments in this field. The most important issue is to have sound surgical principles, and understand that the laser is only an adjunct to good surgical practices!

- *Lynn Powell*: Take courses to learn about lasers. Observe dentists using them and receive appropriate training.

We thank you, dear Colleagues, for answering our questions and giving personal findings and recommendations.

CURRENT ORAL LASER SURGERY

The CO₂ laser beam was introduced in oral laser surgery in 1980, and it revolutionized the field. Its effects on oral soft tissues offer many advantages: bloodless surgery, decontamination of the surgical site by heat generated, no need for suturing healthy patients, simplicity of use, and perfect control of the removed tissues. In addition, using the CO₂ laser beam improves the tissue quality of the healed area due to collagen secretion induced by the tissue beam action, and has a bio-modulation effect on irradiated tissues.

This atlas will examine and discuss some procedures common in different fields of current oral surgery. First, we present an introduction to laser physics, as well as guidelines for proper clinical protocol. Then, we examine how the laser beam can be useful to practitioners in different specialties, such as periodontics, endodontics, orthodontics, implantology, pre-prosthetic surgery, and oral soft tissues diseases treatments. Over 200 full-color photographs accompany step-by-step surgical procedures including frenectomy, removal of infected tumors, ablation of benign tumors, gingivectomy, treatment of vascular lesions, treatment of hyperkeratosis, and vestibular deepening. Finally, we engage in a round table discussion with some of the best international experts in the field of oral surgery.

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